INTERNATIONAL LABOUR OFFICE

OCCUPATION AND HEALTH

ENCYCLOPAEDIA OF HYGIENE, PATHOLOGY AND SOCIAL WELFARE

Volume I

A – H

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And whereas conditions of labour exist involving such injustice, hardship and privation to large numbers of people as to produce unrest so great that the peace and harmony of the world are imperilled; and an improvement of those conditions is urgently required: as, for example, by

*the protection of the worker against sickness, disease* and injury arising out of his employment, the protection of children, young persons and women.

Preamble to "Labour" Part of the Treaties of Peace.
LE MINIERE DEL RAME

(Galleria degli Uffizi - Firenze)
In the brief introduction which the collaborators in this Encyclopædia of Industrial Hygiene have written for their work, the origins of the publication are clearly stated.

In 1919 the International Labour Conference at Washington requested the International Labour Office "to draw up a list of the principal processes to be considered as unhealthy". But it was impossible in practice to draw up such a list, at least in a complete or final form, on account of the number and complexity of the operations which in some aspects could be considered unhealthy, the continuous evolution of industrial technique which does away with causes of disease in one direction while giving rise to fresh possibilities of disease in another, and the indefinite character of the conception of "unhealthiness" which varies at different times and in different countries.

These considerations led to the idea of substituting for the list of unhealthy processes requested by the Conference, a sort of encyclopædia which would analyse from the triple point of view of the work to be done, the worker employed, and the environment in which he worked, the various tasks involved in human labour, the properties of the substances dealt with, the operations involved in handling and working up these substances, the possible sources and carriers of intoxication and disease, the statistical data on the effects as far as known, the symptoms, the diagnosis, the therapeutic and prophylactic treatment, and the protective legislation already in existence.

It was a difficult task, and one which was bound to be open to the reproach of being neither complete nor final. But how could it be otherwise? No one can hope to fix once for all something which is living, evolving, progressive. Although, as was mentioned above, the evolution of technical practice in industry may create new dangers for the worker every day, yet the progress of this same technique and of industrial hygiene may, on the following day, do away with certain existing dangers, which must, notwithstanding, be recorded and analysed in this work. One of the virtues of this work is just the fact that it is not final. It seized one moment in social life and
in the progress of industrial hygiene, but it requires to be kept con-
stantly up to date precisely because it is a scientific as well as a practical
work.

This is its dual nature, as it is that of every piece of research
undertaken by the International Labour Office, the strict purpose of
which is to make science the servant of practical action. This
Encyclopaedia is not a work of pure propaganda; it never sacrifices
scientific objectivity to the ideas which the authors naturally have
at heart. On the other hand, it is not purely a treatise on medicine
or hygiene; it claims no originality in the treatment of the various
questions; it does not claim to be an exhaustive study; on each subject
it merely gives a summary of the existing position of science, with
figures taken from statistics for the sake of example and not in
support of any argument. It has tried to keep a middle path
between a purely scientific work intended for the expert, and a popular
manual. It is meant to supply workers, employers, their organisa-
tions, and practising doctors with the information necessary to enable
them to discover, combat, and prevent occupational diseases, the
economic consequences of which are as harmful to production as
their social consequences are to the world of labour.

In carrying out this plan it has been the privilege of the Inter-
national Labour Office to have the collaboration during the last few
years of eminent experts who have taken part in the compilation or
the supervision of the Encyclopaedia. The International Labour Office
takes this opportunity of expressing its sincere and warm gratitude
to them. They must, however, have already found the first and
greatest recompense for their work in the work itself. Each of them
is an apostle as well as an expert in his own country. All are
living illustrations of the fine, comprehensive definition of "social
medicine" given by Pieraccini: "Social medicine purifies, if one may
say so, the work of doctors; its programme and its essence are purer
and more homogeneous; it removes doctors from contact merely with
individuals and makes them benefactors of the whole human race".

The International Labour Office, in collaborating with these
scientists for some years, has obtained a clearer consciousness of the
scope of its mission. The Preamble to Part XIII of the Peace Treaty
included among the urgent tasks of the Office the protection of
workers "against sickness, disease and injury arising out of their
employment". The signatory States, in agreeing to this statement
of principle, seem to have accepted the dictum of Lord Beaconsfield,
that the health of the people is the most important of all problems.
The Office has put at the disposal of those concerned a statement as
to the actual position of science and has conveyed to the legislator
the elements of physiology and physio-pathology necessary to him
for setting up a code of industrial health; by collecting and concentrat-
The Office is continuing the work of those who, since the inception of "large-scale" industry, have endeavoured to protect human life, openly or insidiously menaced by new technical processes. The fact that the Office was able to secure the collaboration of a good number of these persons is the best proof of its international utility. For many years before the war, the studies of social savants had led to the partial and more or less sporadic introduction of legal protection for the worker against the harmful consequences of his employment. But this edifice, like so many others, was still incomplete and on an insecure basis, so that it was overthrown, if not actually swept away, by the torrent of war. The willing workers on the original building found numerous obstacles in their path when they tried to resume their work, and especially to reunite the bonds of international collaboration. The Office is proud to think that it may perhaps claim the merit of having provided for the first time since the war the means and habit of intellectual co-operation, irrespective of frontiers, for the welfare of all. And it is just because this work was for the welfare of all, and for the protection of human health, that the Office rejoices in the resumption of this co-operation, and in its share in bringing it about.

The Introduction to this Encyclopaedia bears the motto of Ramazzini: Medici munus plebeios curantis est interrogare quas artes exerceant - "The duty of a doctor attending the common people is to enquire what trades they practice". The old practitioner knew well that a knowledge of the patient's trade might be a valuable factor in arriving at a diagnosis. This simple practical piece of advice throws a strong light on industrial civilisation. It is only when dealing with the "common people" that the doctor must think of their occupation. There are numerous sources of disease which do not affect the privileged classes of society, but only that class which Saint-Simon called "the most numerous and the poorest" and which nevertheless by its work gives rise to all wealth, all progress, and all happiness. For a long time this work, which is indispensable to the prosperity of the community, brought the worker nothing but physical, intellectual and moral poverty. But the conscience of the modern world has been awakened to this monstrous social paradox. Too much misery lies behind humble daily tasks; they lead to too much physical, and hence also moral, suffering. "We live", says Pierre Hamp, "on the sufferings of others. Everyone makes life a torment for some of his fellow-men. How many people earn their living pleasantly? All do so in unpleasant and often intolerable conditions. To love one's occupation is to be happy, but where are the occupations which one can love?"

In ancient societies, dangerous and disagreeable tasks were
reserved for criminals. Fourier, for all his fertile imagination, dared not foresee that the progress of industrial technique would one day lead to the suppression of unhealthy or dangerous occupations: he reserved filthy or dangerous work for his "small gangs". Nowadays the problem is entirely different: the conscience of modern society realises that occupational diseases should not be reserved for certain persons, but that they should be made to disappear. The origins and the causes are now known, and all that is wanted is will and organisation. There are plenty of other sufferings and plenty of other infirmities to which mortals are exposed. As Puccinotti has said: "Life must be preserved for labour, and labour must be made harmless to life". Work must be healthy if it is to be pleasant and agreeable and if some of the causes of that "unrest" which, as Part XIII of the Peace Treaty says, is "so great that the peace and harmony of the world are imperilled" are to be done away with.

It is hoped that this modest work which the International Labour Office has prepared by patient toil and now offers to the judgment, and still more for the service, of workers, employers, and society as a whole, may contribute its share to realising this high ideal. The efforts of its editors have been directed towards rendering science a guide to practical action. This aim will have been achieved if the work appears to be an indispensable part of that edifice, the erection of which will be the next task: the international code of hygiene and industrial health.

ALBERT THOMAS.
INTRODUCTION

Medici munus plebeios curantis est interrogare quas artes exerceant.
RAMAZZINI.

ORIGIN OF THE WORK

During the First International Labour Conference, which met at Washington in October 1919, the Commission on Unhealthy Processes adopted the following resolution:

"It should be referred to the International Labour Office to draw up a list of the principal processes to be considered as unhealthy."

The Commission admitted, however, that it felt embarrassed by the absence of any definition of what constituted an "unhealthy process".

On the proposal of one of the delegates, the Conference recommended that the Health Section (the creation of which within the International Labour Office was then contemplated) should be entrusted with the work of drawing up the list in question, since such work was naturally one of its functions. "So far as the injurious processes are concerned it is not primarily a case of investigating main principles. As a rule, it is the detailed examination of how to apply particular precautions to varied and different industries, and that means an examination of a great mass of statistics and analysing chemical and medical data."

For some years the question of unhealthy industries has attracted the attention of experts and even of public opinion, which has demanded legislative action, sometimes international action, on lines likely to produce the best possible results both for industry and for the worker himself. Such action for the diminution, and in some cases the entire abolition, of all serious occupational dangers is a worthy task, but cannot but be slow, since unhealthy occupations are very numerous and often very complicated. Although certain industries cannot for the time being be made completely innocuous, the progress of modern science and technique enables far-sighted employers, conscious of the advantage to be gained therefrom by industry, to adopt measures and new processes which tend to make dangerous processes less dangerous. It should not be forgotten, however, that scientific progress leads to the discovery or creation of products and processes which, when adopted in industry, are often a source of new dangers to the worker. Unfortunately, occupational risks do not lurk only in the raw materials, in the finished product,
or in by-products, but are often concealed in intermediate manufacturing operations and are only detected by the experts when disease has already attacked the worker.

The expression "Prevention first" is often heard. That is all very good, but in order that adequate and complete prophylaxis may be organised, it is first necessary to examine the patient, know the disease, its etiology, its pathogenesis, its symptoms, its evolution, and, above all, its extent in the strata of society affected — in this case amongst the working classes. Without this preliminary knowledge, there can be no question of prevention.

**EARLIER EFFORTS**

Even before health experts considered the question of drawing up lists of unhealthy processes (see, for example, Layet's work, published in 1875), legislators had contemplated similar lists, though from a different point of view. Such lists of undertakings classified as dangerous, unhealthy, or obnoxious are more concerned with the nuisances and dangers which such undertakings may involve for the neighbourhood (e.g. smells, smoke, fumes, waste water, danger of fire or explosion) than with the health of the workers in the factory itself. Later, under pressure of public opinion, legislators were compelled to draw up a list of the processes on which the employment of children, women, or young persons should be prohibited, or only permitted under certain conditions.

It is impossible to refer here to all the pioneers in industrial hygiene and pathology who dealt with this question, or all the treatises on the subject [see article "Occupational Diseases: Historical Review"]. It will be sufficient to mention some of the "lists of industrial poisons".

The earliest to appear were the list drawn up at the instigation of the International Association for Labour Legislation and those published on their own initiative by certain scientists; for example, that drawn up in 1908 by Sommerfeld in collaboration with Oliver and Putzeys (Jena, Fischer, 1908) and revised in 1910 by Fischer (Frankfort-on-Main, Aug. Weisbrod), and Sommerfeld's later list of 1910 (Jena, Fischer). More recently there have been the lists of Müller, of Zurich (1919), of Kober and of Wadsworth (in Kober and Hayhurst's treatise on industrial hygiene), the pamphlet of the Metropolitan Life Insurance Company (New York, 1921); that of the Bureau of Labour Statistics (U. S. Department of Labour, Bulletin No. 206, Washington, 1922), the pamphlet drawn up by Dr. Robertson, of the Industrial Health Division of the Australian Ministry of Health (Melbourne, 1923), and finally, Industrial Diseases: Rapid Reference Manual for the Use of the Medical Profession, arranged by C. T. Graham-Rogers, M.D., Inspector of Factories, New York State Department of Labour, Division of Industrial Hygiene (1924). The Industrial Poisons Committee (Chemical Section) of the National Safety Council of the United States submitted to the 1924 Annual Congress a study entitled *Summary of Present Practice in Industrial Poisoning Prevention*. In 1925 there appeared the second edition of the *Aerztliche Merkblätter*, dealing with occupational poisoning and injuries resulting from chemical substances, edited by the Association
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of Factory Doctors in the German Chemical Industry (Verlag Springer, Berlin).

The lists, which were at first confined to giving in tabular form the data concerning industrial poisons (e.g. industries and processes in which poisoning may occur; mode in which poison enters the system; symptoms; special measures), have little by little been extended to include all other causes of disease, such as temperature, compressed air, humidity, dust, infection, etc. This logical and necessary development of the lists shows clearly that the term “unhealthy” is not limited to its former restricted sense, which only covered poisons.

Scope of Present Volume

In these circumstances, and for other reasons which need not be urged here, the compilation of an international list such as that contemplated by the Washington Conference becomes extremely difficult, not to say impossible. It may be considered that the most practical solution would be the preparation of national lists drawn up by each country separately; but at the same time it is the function of the International Labour Office to collect and publish all information which will enable experts and the authorities concerned to learn what has been done and suggested in this field in the various countries. Such information, which would be the objective result either of a permanent investigation in the various States Members of the International Labour Organisation or of data drawn from published works and carefully checked, is of the utmost interest to manufacturers, workers, medical inspectors and industrial experts, medical practitioners, experts, etc.

Acting in accordance with the spirit, if not the letter, of the Washington resolution, and in agreement with its Correspondence Committee on Industrial Hygiene, the Office decided to interpret the

1 The treatises on occupational diseases and industrial hygiene of Pieraccini, Loriga, Carozzi, Giglioli, Ranelletti, Ferrannini, for Italy; of de Mosny, Sergent, Balthazard, etc., for France; of Hope, Hanna and Stallybrass, Oliver, Prosser White, etc., for Great Britain; of Weyl, Rambousek, Lehmann, Gotstein, Schlossmann and Teleky (Vol. II. of Treatises on Social Hygiene, 1928), of Chajes (1929), etc., for Germany; of Löwy, for Czechoslovakia; of Hejermans, for the Netherlands; of Kober and Hayhurst, Alice Hamilton, etc., for the United States; the reports of the proceedings of national and international congresses on occupational diseases and hygiene; of original articles appearing in technical periodicals: Journal of Industrial Hygiene (Great Britain and United States); Public Health Reports, the American Journal of Public Health, the Industrial Doctor (United States); La Medicina del Lavoro, La Rassegna di Previdenza Sociale (Italy); Zentralblatt für Gewerbehygiene (Germany); Zeitschrift für Gewerbehygiene (Austria); Annales d’Hygiène publique, industrielle et sociale (France); Bulletin de l’Inspection médicale du Travail (Belgium); Bollettino del Lavoro e della Previdenza (Italy); Higjena Pracy (Warsaw); Gigiena Besopastnost i Patologia Truda (Russia), etc.; the medical press of various countries, etc.; the theses; the chapters dealing with the factor “work” in treatises on special subjects; the treatise by Oppenheim, Ulman and Rille on skin diseases of occupational origin (Verlag Voss, Leipzig, 1926); the treatise on toxological chemistry by Kober (Germany), by Ogier and Kohn-Abrest (France), etc.; the treatises on diseases of women, diseases of the eyes, etc.; the most important publications on technology and industrial chemistry, etc.
word “unhealthy” in the widest possible sense, so that in addition to toxic, infectious, and parasitic causes of disease the articles cover all other causes capable of endangering the health and life of the workers.

**Scheme of Compilation**

The series to which this forms an introduction deals therefore with three main groups of questions:

1. The work.
2. The worker.
3. The environment.

The work is analysed into its constituent elements, such as materials, industries, trades, and causes of disease (chemical, biological, etc.). Each article is prepared on a uniform plan, which in the case of causes of disease includes the following subdivisions: chemistry or biology; sources of poisoning or of infection; uses of the dangerous product; its mode of action; statistics; symptoms; diagnosis; method of detection in the environment or the individual; prevention; legislation; bibliography.

Industrial technique is described in the order of the operations involved, showing in each case the peculiar dangers involved and the requisite preventive measures. The scope of the technical descriptions is determined, on the one hand, by the nature of the unhealthy conditions and, on the other, by the preventive measures employed or prescribed by legislation.

Among the numerous and often detailed statistics in the possession of the Office, those have been selected which are the most recent and deal with the essential facts.

In general, the figures selected are restricted to absolute figures or relative values cited by authors or factory inspectors, without any attempt being made to interpret or compare these. The statistical methods followed being very varied, the number of workers engaged in a given factory visited or exposed to a given risk being unknown, it would be highly imprudent to analyse these figures with a view to arriving at any conclusion whatsoever. On the other hand, these figures represent nevertheless an interesting aspect of the question or an indication which deserves to be brought to the attention especially of those desirous of engaging in the study of any given problem.

The subdivision “Dangers” describes the characteristic forms of disease in each industry. In cases of the more important forms of poisoning the reader is referred to the special article on this poison; for example, in the article on “Hair Cutting” a reference will be found to the article on “Mercury Poisoning”. In the paragraph headed “Pathology” the reader is given an account of the morbid forms noted amongst workers engaged on the processes in question. Similarly, as regards legislation, a brief summary, is given of measures for the protection of women, young persons, and, where such exist, of adult men, with information as to provisions on the notification and compensation of industrial diseases, special legislation, etc.

The worker is considered in relation to the products with which, and the environment in which, he works. The object of the articles
on the physiology and pathology of the various organs and systems, personal and collective hygiene (including medical or social welfare within the factory), etc., is mainly to recapitulate the data given under the headings of industries and causes of disease. They are, to some extent, a more complete review of problems which could not be dealt with in detail in the technical articles (e.g. an article on the eye summarises the various diseases of that organ encountered in the various industries).

Under environment fall general studies on subjects such as atmosphere, premises, heating, lighting, removal of dust, gas and fumes, humidification, etc. Sanitary accommodation (cloak-rooms, lavatories, privies, etc.) is dealt with in a single article entitled "Personal Hygiene". These studies, based on data furnished by up-to-date industrial hygiene, are treated separately with a view to avoiding repetition.

Limitations

Every effort has been made to make as complete a statement as possible on each subject, but obviously it is very difficult, for example, to classify the dangers which threaten the worker in their order of gravity: there are too many factors involved, even in a single country. This is an essentially national question, indeed, in some cases a local one, which cannot be taken into account here.

In fact, the same industry, the same process even applied in two different factories, though these may be for instance in the same town, will exert different effects on the health of the workers in accordance with the special conditions under which the work is carried out (workrooms, varying methods of work, up-to-date plant or otherwise, health supervision, etc.).

It is equally difficult to make a distinction between definitely established facts and data which may seem doubtful or inaccurate. In each individual case enquiries are made of qualified experts on any point which, on revising the articles, the members of the Correspondence Committee on Industrial Hygiene think doubtful. After this consultation, the Office takes the final decision that it thinks proper. It should nevertheless be emphasised that all the data published, although the result of the most detailed research and of information collected with the utmost care, cannot be considered as final.

The hygienic and health conditions dealt with in the various articles must not be considered as the result of a permanent enquiry at present conducted by the Office. They merely represent the results of investigations conducted by experts or by factory inspectors in the most varied localities and also at very different dates. Obviously these results are neither comparable one with another, nor can they be regarded as a "photographic" representation of the present state of the industry in question, and still less that of any one factory in particular, which could have no ground whatsoever for imagining that the conditions as stated in the articles might imply criticism of its methods.

It has been said that science is revolutionary. Like matter, it is always in process of transformation; therein lies its great strength and its raison d'être. Science lives only because it doubts, because
it refuses to accept as fixed and final the truths enunciated even by
the most eminent authorities. In science there exists no authority
which can settle a question finally, putting one party in the right
and the other in the wrong. This being so, in preparing the *Encyc-
lopaedia* the custom of placing in parentheses after a statement of
opinion the name of the author responsible therefor has been generally
followed.

The section dealing with "legislation", which is as up-to-date as
possible, is not intended of course to include all legislative measures
on any given subject, but merely seeks to give the most characteristic
or important provisions as examples. Similarly, in the "bibliogra-
phies" at the end of each article there are only mentioned the most
recent and important works, which will enable the reader to refer to
general bibliographies on the subject. In this connection it may be
recalled that the Office publishes quarterly a very detailed *Bibli-
ography of Industrial Hygiene* classified by subject and by author.

It was further decided to illustrate certain parts at least of this
publication (e.g. articles dealing with industries and hygiene) with
photographs, sketches, diagrams, plans, etc., showing recent innova-
tions and improvements. The work is completed by a series of cross-
references and an alphabetical table of contents which will facilitate
readers' enquiries.

The publication, therefore, will have neither the systematic form
of a list nor the scope of a large treatise on hygiene; its only object is
to furnish as wide and accurate information as possible on questions
which are of daily occurrence in the world of labour, in connection
with hygiene, pathology, and medical aid.

In order not to make the work too voluminous, it has been thought
well to condense the articles, though without sacrificing any essential
matter, in effect to adopt a somewhat telegraphic but nevertheless
clear and intelligible style. The technical and medical sections in
particular are made neither too concise for the uninitiated to under-
stand them, nor so detailed as to be unintelligible except to one or two
experts, who in any case are already acquainted with the subject or
could look it up in other documents.

Medical men will no doubt note omissions in the various articles
and sections on occupational diseases (especially in the data relative to
morbid anatomy and therapeutics). These omissions are deliberate,
since the work is intended not solely for doctors, who can, if necessary,
find the information they require in any medical handbook, but also,
and above all, for workers, manufacturers, and their organisations.
The chief object is to disseminate as widely as possible the informa-
tion required for the detection of occupational diseases, to indicate
the steps to be taken for their cure and prevention, and to lay down
general principles for the better protection of the workers.

**Expert Collaborators**

In view of the extensive knowledge and experience required for
this publication, and of the responsibility assumed by the Office in
preparing and issuing it, it has been judged essential, in drawing-
up the plan of work and in drafting certain articles, in addition to
enlisting the aid of the members of the Correspondence Committee on
Industrial Hygiene, to appeal to certain of the foremost experts in the various countries who were considered as being particularly fitted to write one or other of the articles.

The articles written by collaborators or by the Health Service are submitted for consideration to the members of the Correspondence Committee on Industrial Hygiene and to experts in the particular subject. The final text of each article has been drawn up on the basis of the information and suggestions received by the Service.

Each article has been signed by the author of the original report. The signature replaces the formula adopted in the brochure edition: "According to an original report by ........................., revised by the Correspondence Committee on Industrial Hygiene of the International Labour Office". Where the original text has been prepared by the Hygiene Service under the responsibility of Professor L. Carozzi, Chief of the Hygiene Service, it is marked thus ***. This sign replaces the above-mentioned formula.

The work appeared at first in the form of separate brochures. The present edition in volume form contains many modifications and additions rendered necessary by subsequent discoveries, new conceptions and observations furnished by science and technology subsequent to the publication of certain articles. It may therefore be said that this volume represents a new, revised and extended edition of the work already published in pamphlet form.

The Office takes this opportunity of acknowledging the valuable assistance given by Dr. Legge, formerly Senior Medical Inspector of Factories in Great Britain, and by Professor E. L. Collis, University College of South Wales and Monmouthshire, Cardiff, in the preparation of the English translation of the articles, a task which, in view of the many technical terms employed, was one of unusual difficulty and responsibility.

Like the pamphlets, the volume appears in the two official languages of the Office, English and French.
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1 The names of the members of the Correspondence Committee on Industrial Hygiene and the Safety Committee of the International Labour Office are preceded by an asterisk.
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Thallium.
Thorium.
Timber Industry.
Tin.
Titanium.
Tobacco.
Toluene.
Tortoiseshell.
Transport Workers.
Trinitrotoluene.
Tripe and Gut Works.
Tuberculosis and Silicosis.
Tumours of Occupational Origin (Occupational Cancer).
Tungsten.
Turpentine.
Type Founders.

Ultramarine.
Uranium.

Vanadium.
Varnish and Lacquer Manufacture.
Ventilation.
Vocational Guidance.

Watch and Clock Makers.
Welding (Autogenous).
Welfare Workers.
Wine and Spirits Industry.
White Lead.
Women's Work.
Woollen Industry.
Woollen Industry (Disinfection).

Xylene.

Zinc.
OCCUPATION
AND
HEALTH
Abattoirs — Slaughterhouses


Abattoirs are the premises where butchers slaughter animals intended for food.

On these premises are carried on all the operations required for the preparation of butcher's meat; and here also are temporarily accommodated animals awaiting slaughter.

The slaughtered animal passes to a workman, who makes an incision following a ventral line the full length of the body and then two others at right angles to the preceding line, one for the fore-limbs and the other for the hind-limbs; these incisions sever the skin of the limbs right up to the extremities. The flaying is usually done with a knife, but the men who undertake this work are specialists. One skins the front legs, another the head, another the shoulder, etc. Each is supplied with a knife designed for the particular work which it has to do. These workmen rapidly acquire extraordinary dexterity. In five or six minutes an animal is flayed and the hide is always undamaged (United States). In some abattoirs (for example, at Zurich) the flaying of animals is done by means of an apparatus which enables the work to be done without the fatigue occasioned by skinning with a knife.

Slaughtering, cutting up the meat, the various changes it undergoes, the waste, blood, offal, and guts are all causes of unhealthiness in this industry.

It may be mentioned here that the work done in abattoirs is also done, especially in small centres and in the country, at the house of the butcher or pork-dealer.

The knacker kills, skins and cuts up dead or injured animals. In towns the knacker's work is done in municipal yards under strict supervision.

The knacker's trade, especially the part relating to the hygiene of food, ought to be regulated on a uniform system. Too often the knacker is also a butcher; too often the meat from the knacker reaches the sausage factory; too often animals who have died of disease are buried at the risk of infecting the land.

Knacker's work includes treatment in closed vessels by steam under pressure, by chemical reagents, incineration, dry distillation, and burying in special enclosures authorised for this purpose and closely supervised.

Sources of Danger

In addition to the smells arising from animal material in a state of putrefaction and from decomposing water, there are, it must be recalled, also risks from escaping animals and especially from contamination by animals affected with diseases transmissible to man, e.g. anthrax, glanders, Bang's disease (bac. abortus), erysipelas, actinomyces, and trichinosis, which attack slaughterers, cutters-up, cattle-yard men, veterinary officials, and others.

Traumatic lesions from accidents caused by the animals are also common.

Statistics

According to some figures, a little out of date (1903-1905), dealing with 2,150 female members of the local society of butchers of Berlin, 620 persons were sick with incapacity for work; 5.6 per cent. of members showed lesions arising from accident, 3 per cent. from troubles of the genital organs (menstruation, abortions, etc.), 2.4 per cent. from digestive troubles, 2 from acute infections, 2 from respiratory diseases, 2 from anaemia, 0.9 from nervous diseases, and 0.8 from diseases of the circulation. A group of 4,200 men had 2,125 sick with incapacity, i.e. 50 per cent.; traumatic lesions (accidents) figure as affecting 19.5 per cent. of members; venereal diseases, 9.8; respiratory dis-
eases, 3.6; rheumatism, 2.7; dermatitis, 2.4; digestive troubles, 2.3; infections, 2; nervous diseases, 0.9; and diseases of the circulation, 0.8 (Leiser). According to the last report of Leipzig (1910), butchers, as regards length of illnesses, show figures of less than the average invalidity rates; the records being equal to half the average for infections for circulatory diseases and digestive troubles, equal to a third of the average for respiratory diseases, and equal to a tenth of the average for tuberculosis. More frequent than the average, on the contrary, are troubles due to infectious diseases of the skin, where a small wound easily becomes infected, and eczema.

Some American statistics (United States, 1910) dealing with about 125,185 butchers give the following results:

<table>
<thead>
<tr>
<th>Age group</th>
<th>Deaths</th>
<th>Typhoid fever</th>
<th>Pulmonary tuberculosis</th>
<th>Cancer</th>
<th>Appendicitis and paralysis</th>
<th>Diseases of the heart</th>
<th>Pneumonia</th>
<th>Chronic nephritis</th>
<th>Accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>25-34 years</td>
<td>298</td>
<td>3.4</td>
<td>39.4</td>
<td>1.4</td>
<td>1.9</td>
<td>5.3</td>
<td>10.1</td>
<td>5.8</td>
<td>8.7</td>
</tr>
<tr>
<td>35-44</td>
<td>253</td>
<td>4.1</td>
<td>22.9</td>
<td>4.8</td>
<td>2.7</td>
<td>8.6</td>
<td>8.5</td>
<td>8.2</td>
<td>8.2</td>
</tr>
<tr>
<td>45-54</td>
<td>341</td>
<td>1.8</td>
<td>13.8</td>
<td>6.7</td>
<td>4.1</td>
<td>13.5</td>
<td>5.6</td>
<td>5.3</td>
<td>6.5</td>
</tr>
<tr>
<td>55-64</td>
<td>295</td>
<td>0.3</td>
<td>6.8</td>
<td>12.5</td>
<td>11.5</td>
<td>12.2</td>
<td>7.5</td>
<td>13.2</td>
<td>3.4</td>
</tr>
<tr>
<td>All males on census</td>
<td>—</td>
<td>2.2</td>
<td>14.8</td>
<td>5.5</td>
<td>7.3</td>
<td>11.9</td>
<td>8.0</td>
<td>8.3</td>
<td>10.5</td>
</tr>
</tbody>
</table>

**PATHOLOGY**

Persons employed in abattoirs and butcheries are generally young, healthy and strong, without defects of organs of sense. Where women are concerned, vigorous young girls are met with, of strong constitution, able to lift heavy weights, and even employed at strenuous work for long hours.

If, as statistics show, pneumonia and tuberculosis are rare, nevertheless a certain frequency is found of bronchitis, tracheitis, and diseases of the throat, caused by the sudden changes of temperature. Rupture of muscles, hernia, varicose conditions, and flat foot are in strict proportion to the efforts required by the work and to the amount of standing. Pathology is, however, especially concerned with infections. According to Boxeden (1904) pemphigus of butchers, called by Colcott Fox "acute febrile pemphigus", is a general infectious disease due to handling the skins of certain diseased animals; it is only the human form of aphthous fever (foot and mouth disease). But the latter infection seems much less serious than pemphigus. It usually starts with a prick on the fingers; it shows itself by an erythematous rash, an eruption localised to the throat, accompanied by headache, and followed by desquamation. Brocq has collected 25 cases, of which 17 were fatal in 10-15 days. In 1873 some cases of erysipelas among butchers had already been noticed (Morrant Baker). So called migratory erythema, chronic erythema and, by V. Redwitz, "erysipeloïd". Gilchrist, in his clinic at Munich, 26 cases in 1922 and 46 in 1923, generally among persons who by their trades are brought in contact with the carcasses of fish or of animals, and particularly those of pigs, who in about half the cases, without being ill themselves, are carriers of the bacillus of erysipelas in the intestines or on the tonsils. The illness may be caused by hypnocytes (the "cladothrix", Rosenbach, 1884), and the clinical features caused by this fungus appear similar to those seen among laboratory workers who handle cultures of the erysipelas of pigs. It has thus been possible to identify the two diseases, and it is even reported that their causative agent has a singular resemblance to "bacillus murisepticus".

Among the 46 cases of V. Redwitz, 8 had slaughtered pigs suffering from erysipelas, 3 diseased pigs, 16 had handled pigs' meat, 2 the meat of hares, and 9 had worked in kitchens. Some cases have also been caused by the bites of lobsters, crabs or cray fish, which are liable to come in contact with the carcasses of animals.

The affection is generally confined to the hand and especially to the fingers, sometimes to the neck and abdomen. It does not become generalised and it is only in 10-15 per cent. of cases that such symptoms of generalisation are encountered as superficial lymphangitis of the arm or forearm. The prognosis is favourable; a fatal issue is rare.

Secrétan in one case of rhinoscleroma attributed the contagion to the fact that the sick woman sorted dried guts sent into Switzerland from Hungary and Russia; other writers have reported
cases of contamination from contact with the carcases of animals.

Matzenauer, of Vienna, in 1908 described a palmar hyperkeratosis among butchers due to the handling of pig bristles. Some cases have also been reported of tuberculosis verrucosa, dermatomycosis, and folliculitis, due more particularly to ectothrix trichophyton affecting horses, cows and pigs; of taenia and trichinosis from the consumption of uncooked meat; of actinomycosis, bovine tuberculosis, and of Bang's disease due to the bacillus abortus (case of Viviani, 1925) among butchers or stable boys who come in contact with cows affected with this disease. More important and more serious are the cases of anthrax infection which in Germany, for example, showed, for the period 1910-1921, the following figures:

<table>
<thead>
<tr>
<th>Number of cases</th>
<th>Number of fatal cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abattoir workers, butchers, sellers of cattle</td>
<td>316</td>
</tr>
<tr>
<td>Flayers</td>
<td>49</td>
</tr>
<tr>
<td>Veterinary surgeons and inspectors of abattoirs</td>
<td>15</td>
</tr>
</tbody>
</table>

In 1923 the number of cases of anthrax was 26 of which 25 (with two deaths) occurred among the abattoir workers and butchers, and one among the flayers.

**Hygiene**

Without entering into details concerning the construction of abattoirs, their locality, the installation of light, ventilation, and of water under pressure, which belong to the domain of municipal hygiene, certain points in the hygiene of abattoirs and butcheries may be reviewed here which have reference to the prevention of diseases affecting persons occupied in this trade.

It is a fact that the abattoirs and butcheries of small communities are usually in a worse condition than those of the average community and big towns. They should comply with certain minimum conditions of working in order to ensure good hygienic conditions: water under pressure should be laid on; the floor should be impermeable, smooth and washable; drainage is needed for washing down and for blood; the walls, exposed timber and woodwork should be washable; and general daily cleansing should be practised. The keeping of pigs and poultry in abattoirs and feeding them with offal should be prohibited; war should be waged against rats on the premises.

Animals should be prevented from wandering freely into the yard; they should be fastened securely during their stay in the cattle-market pens; a method should be adopted to enable them to be easily seized; there should be a system of movable barriers to direct the animals when disembarked from the cattle trucks into the slaugh- terhouses without any possibility of their escaping.

All the large towns have special regulations for abattoirs and special measures for cow-houses, pigsties, purifying houses where waste offal is burnt, and where meat to be stored is hung up, and for tripe shops.

Abattoirs, in some countries, often possess apparatus for extracting and rendering down fats, and scalding houses where parts of animals suitable for food and offal intended for industrial purposes are submitted to the action of hot water.

In this case every precaution for the most efficient condensation of gaseous products must be taken and for recovering any which have not been condensed in the drying gazogene. They should be made to pass out through the furnace. Efficient ventilation of the knackers' premises is required; and also daily removal of hair, horns, hooves, skins, etc., in impermeable, water-tight carts which are completely closed. The materials coming from the purifying tanks and those which have escaped the cooking process should be converted into manure by mixing them with absorbent substances.

Eating, drinking, or sleeping in the workshops should be prohibited. There should be placed at the disposal of the staff lavatories with efficient disinfectant solutions, together with a service of sanitary supervision both for the animals and workmen.

A campaign must be undertaken against nauseating smells (see article "Odours"); and also with a view to obtaining efficient removal of offensive smelling steam. Offal, such as horns and hooves, must be stored in well-ventilated places and covered with quicklime.

Thorough daily cleansing and weekly disinfection, with chlorine or formaldehyle, of places soiled by debris and slop water must be carried out.

Treatment of debris in special apparatus, every operation being done in a closed vessel, is essential and prevents any inconvenience.

The question of waste water charged with organic matter and able to infect rivers is also important. The water, after having been decanted into
a special tank, is submitted to the action of anaerobic microbes in a septic tank and passed successively over bacteria beds by means of a distributing system carried out by pipes and channels, which run the water on to the fields; there it is subjected to the action of nitrous and nitric aerobic microbes (see article "Waste Waters").

Compulsory notification should be required from every owner of an animal which dies of any disease; while the possibility of an owner destroying a dead animal without having recourse to a knacker's yard, if one is not available within a fixed radius, should be provided against; measures must be taken for burying carcases especially when infected animals are involved (Martel).

Legislation

Women are rigidly excluded from stores of animal debris, of manure of animal origin, from washing and preparing of guts (Argentina), and from the inflation of guts (France). Youths of less than 14 years are excluded from public and private abattoirs for slaughtering work and other work carried out on these premises (France); of less than 16 years from cutting-up departments, storerooms of animal offal, animal manure works, public and private abattoirs, gut-cleaning places, and knackers' yards (Belgium); of less than 17 years from public and private abattoirs and slaughtering of animals (Portugal) and of less than 18 years from the workshops for inflating and drying bladders (France). Boys of less than 16 years are forbidden to handle the debris of abattoirs, to slaughter animals, and to work in glue works (Quebec, Canada); to work in private abattoirs, out-houses and storehouses of offal with a view to the extraction of various nitrogenous substances; to clean and remove bladders and guts; in the rooms where the work of cleaning and blowing up is carried on (Spain). Young girls of less than 18 years are excluded in Canada (Quebec) and those of less than 21 years in Spain from scalding houses where intestines, offal and other animal debris are prepared and cooked, and where the heads and feet of animals are treated to separate the hair; from stores and the drying of blood; and from separation of mucous membrane of guts by putrefaction in catgut factories.

For notification or compensation of diseases, see the articles concerning them. Notification of cases of inflammation of the skin and of the subcutaneous cellular tissue among gut cleaners is also provided for in Holland.

Compensation for septicemia in all work involving the handling of meat, or the manufacture of food products, or of animal by-products is provided for in Queensland and in the State of Victoria.

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Abrasives (Artificial) and Grinding Wheels

Raw Material

The two artificial abrasives in most common use are emery and carborundum in crystalline form. The wedge-shaped crystals are almost as hard as diamonds. Considered from the point of view of their physical characteristics, these crystals in dust size should be equal in danger to any type of dust met with in industry.

Emery (French : émeri. — German: Schmirgel, Potterstein. — Italian: smeriglio. — Spanish: esmeril) is an aluminium oxide manufactured from bauxite in a water-cooled furnace, the heat being very intense and produced by an electric arc. The fused crystals of aluminium oxide form a large mass or "pig" in the furnace after cooling. This pig is removed from the furnace and broken up by men wielding sledge hammers. The ore is then crushed to a fine grain which in turn is screened to different sizes. The number of the powders corresponds to the number of wires to the inch in the sifting machine. The reddish brown dust is sold as emery and the white dust is retained as alundum which serves for the manufacture of refractory products. The grain is stored in kegs and either shipped direct to customers, or is used in the manufacture of grinding

Fig. 1. — Dust from artificial abrasives (enlarged sixteen times).
wheels. Emery is also got from emery rock (in Smyrna and the Island of Naxos) which is likewise an anhydrous oxide of aluminium (Al₂O₃).

In the manufacture of carborundum, which is a carbide of silicon (Si₃C), sand, coke and sawdust are mixed and packed around a carbon core. According to Acheson, a mixture of 455 parts of coke, 365 of sand and 180 of salt is used. Sea salt does not participate in the reaction but serves to remove the impurities of the silicon and of the coke in the form of chloride. Sawdust acts as a support for the porous mass and serves to facilitate the elimination of carbon-monoxide. The whole mass is then sided with brick, and the two ends of the carbon core connected with a high-power electric current for 7 to 8 hours. A resistance type of furnace is thus formed. The intense heat along the carbon core causes a chemical change in the coke and sand resulting in a deposit of crystals of carbide of silicon.
along the core of the furnace. The metal thus recovered consists of concentric masses which, the further one recedes from the axis of the apparatus, that is, the line uniting the electrodes, are composed of: a layer of impure carborundum; a layer of the same product (pure enough to furnish the commercial product); a layer of amorphous carbide of silicon; and a layer of the mixture which has not been attacked. Treatment of this mixture produces a quarter of its weight of commercial carborundum.

While the furnace is active a large amount of carbon monoxide gas is generated which, unless the ventilation is good and the process carried on in spacious buildings, produces headache and other symptoms of mild carbon monoxide poisoning.

The resulting pig of carbide of silicon is broken up and reduced to grain under steel grinding mills placed in cast-iron tanks. The grinding does not involve undue wearing of the apparatus because the carborundum is fairly easily broken. It is then left
for seven days in sulphuric acid diluted with its own volume of water in order to reduce the iron produced by the mills, then washed in water. The carborundum crystals are then classified according to size, a process rapidly and accurately executed by depositing the various grades in a series of reservoirs increasing in size, and through these is made to pass a current of water in which the crystals remain in suspension. According to the time taken in depositing, the material is divided into the “six minutes” powder (which is the finest and is sold to the lapidaries for diamond polishing), the “four minutes” powder (which is used for polishing glass), etc.

The crystallised-carborundum in a pure state is in form of colourless transparent crystals, while commercial carborundum is opaque and blackish in colour on account of the impurities which it contains (especially carbon). Hardness: 9.5; 70 per cent. content of silica and 30 per cent. of carbon; density: 3.12. Amorphous carborundum, obtained as a by-product in the manufacture of crystalline carborundum, is infusible, and is resistant to most chemical reagents except caustic potash.

**Uses**

It is very widely used in powder or in moulds as a substitute for emery in polishing, sharpening and pointing metals; cutting, polishing, engraving glass; polishing of diamonds, precious stones, and mother of pearl; polishing of leather, marble, hard stones (granite); and mounting of drilling and boring machines in quarries and mines. It is used in the making of wireless crystals, and in the construction of refractory materials and apparatus. Mixed with coal and silica, it is used for the manufacture of such products as “Cryptol” and “Carbofrax” for finishing the grinding wheel (on the left is seen the small cutting wheel), with the suction duct which catches most of the dust generated.
stoves, and electric apparatus, lining of metal ovens, manufacture of crucibles, bricks, etc. It serves to preserve from undue wear and tear cement hearths when strewn over the cement in the form of a surface layer before hardening.

DANGERS

The manufacture of these two abrasives in the electric furnace presents three health hazards: the exposure of the worker to intense heat, the exposure of the worker's eyes to the ultra-violet and infra-red of the arc furnace, and the exposure of the worker to carbon monoxide gas. There are in addition two physical hazards: the danger from large flying pieces or chunks of abrasive when the "pig" is broken up, and the danger to the eyes of flying particles of abrasive in the air.

The above hazards, however, apply only to a very small proportion of the workers in the abrasive and grinding wheel industry, and are such that they can be readily guarded against, so that as a matter of fact these hazards have not resulted in unfavourable health and accident experience.

The manufacture of grinding wheels presents no health hazards except that of the crystalline dust of the artificial abrasives above described. The process of making a typical grinding wheel is as follows:

Suitable proportions of grain of required size and character are mixed with clay and water (generally 70 per cent. carborundum and 30 per cent. clay) in a mixing kettle. Gum lac, gum arabic, oil, soda, soda silicate are also used as cohesive agents, but they are not so good as clay. They, however, offer the advantage of being more elastic and less susceptible to breaking. After having been thoroughly mixed, the resulting semi-liquid mass is poured into rings which are approximately the size of the wheel to be manufactured and subjected to hydraulic pressure. To prevent breaking, a copper wire ring is introduced. The ring containing the abrasive clay mixture is then put in a drying room which is heated to about 120° Fahrenheit. In this baking heat the wheel rapidly dries and is then shaped to its approximate size on a potter's wheel. This is a dusty operation and special dust-removing apparatus is necessary for the protection of the worker.

The wheel is now ready for burning and is packed in sand, surrounded by fire brick, and placed in a kiln where it is subjected to continuous heat running in the region of 2,000° Fahrenheit for a week or more. The kiln is allowed to cool and the wheel removed. It is now stone hard and resembles the finished product.

The next process consists in truing the wheel. This shaping to exact dimensions is done on a lathe, the cutting being done by a specially treated steel cup. During this process a large amount of dust is produced which must be removed by suction apparatus built into the truing machine. After the wheel is trued, it is balanced and the hole bushed with lead. This bushing is free from danger of lead poisoning as the hands of the worker do not come in contact with the lead, and the molten lead pots are not kept at a temperature high enough to produce fumes. Although men working at bushing should be cautious of the danger of lead poisoning, in thirteen years' experience in a large grinding wheel factory in America no case of lead poisoning which could be traced to the bushing process has ever been noted. Having been balanced and bushed, the wheel is tested for faults and breaking. This test is effected in a metal drum at a speed of 7,000 revolutions per minute and a grinding mill capable of resistance can be guaranteed.

It will be seen from the above brief description that the only hazard peculiar to the grinding wheel industry is the dust which is produced at various stages of production. The quantity of dust produced is always of great importance; thus, for instance, Winslow found in an American abrasive factory up to 780 mgrm. per 28.52 cubic metres.

The dust produced in the manufacture of abrasives and grinding wheels, as previously stated, consists of hard, wedge-shaped grains. The chemical composition of these grains consists of aluminium oxide, or carbide of silicon, with very slight traces of silica and iron. The trace of silica only appears in the dust of the truing room where it is largely the result of the vitrified clay in the wheel. The amount in the air is too small to have any physiological effect.

The danger of work in the dusty departments is that the continued inhalation of the dust may produce silicosis. (See articles "Dust" and "Tuberculosis").

Tuberculosis often accompanies sclerosis caused by these dusts. In a
large manufacturing plant which has been producing artificial abrasives and grinding wheels for 23 years, the number of cases of tuberculosis among the workers is considerably lower than the reported cases in the city in which the factory is located. In the same factory (Norton Company, Worcester, Mass.), all workers are kept under medical supervision and those working in the dusty departments are frequently re-examined. During the past 12 years there have been three cases of definite silicosis discovered, or less than one-half, of the number of nine years occurring among employees who had worked for over ten years. Probably the result of dust inhalation. From the above experience and the statistics of the 29 cases of tuberculosis discovered at this factory, it is believed that other factories where prophylactic measures had been adopted, bronchitis and emphysema among the workers (26 per cent.) engaged on dusty operations, whilst the rate for the staff as a whole was only 8 per cent. There was no sign of pulmonary tuberculosis.

From the above experience and the experience of others, the dust produced in the manufacture of artificial abrasives and grinding wheels does not appear to be anything like as dangerous as the dust from sandstone, granite cutting, or other trades in which the dust has a high silica content. It is important, however, that the hazard, even though not great, should be minimised by the employment of adequate and efficient hoods and suction apparatus where these can be used, and that all workrooms should be large and well ventilated.

**Hygiene**

The hygienic precautions for workers in the manufacture of artificial abrasives should, therefore, be as follows:

1. For workers about the high temperature arc furnaces where aluminium oxide is fused:
   (a) Protection of eyes by suitable goggles which will cut out the ultra-violet and infra-red rays.
   (b) Protection from heat by hanging chains or screens.

2. For workers in preparation of abrasive grain:
   (a) Protection of eyes from particles of flying abrasive by the compulsory wearing of goggles.
   (b) Protection of the lungs from fine particles of dust by adequate ventilation, and wherever possible dust removal by suction.

3. For workers in the manufacture of carborundum, protection from carbon monoxide fumes by adequate ventilation.

4. For workers in the manufacture of grinding wheels:
   (a) Protection of lungs by adequate dust removal.
   (b) Protection from possible lead poisoning by instruction in the proper cleansing of hands, etc., after handling lead in the bushing departments.
   (c) Protection of the eyes by compulsory wearing of goggles in the truing departments.

5. For all workers in artificial abrasives and the manufacture of grinding wheels:
   (a) A complete physical examination prior to employment.
   (b) Re-examination of men employed in dusty and lead working departments at regular intervals.
   (c) Elimination from the dusty departments of any employees suffering from pulmonary tuberculosis, active or quiescent.
   (d) Good supply of clean, cool drinking water.
   (e) Proper bathing and locker facilities (workers become very dirty from abrasive dust) and provision of working suits.
   (f) Encouragement of outdoor games and sports after working hours.

**Legislation**

Exclusion of young persons under 18 years of age from all work demanding the use of emery, tripoli, corundum, carborundum, for the manufacture and use of polishing wheels or mills in the United States in the States of Delaware, Maryland, Massachusetts, New York, Ohio, Pennsylvania, Wisconsin. (For reporting and compensation of cases of silicosis, see articles "Dust" and "Tuberculosis").

The illustrations have been kindly supplied by the author.

**Dr W. J. Clark**

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Accidents in Industry and the Human Factor


ACCIDENT FREQUENCY

The frequency with which industrial accidents occur is much greater than is generally supposed, and they are so numerous as to constitute a tremendous toll, not only on the health and happiness of the industrial classes, but on economic production. It is stated that in 1907 there were no less than 35,000 fatal accidents amongst the industrial population of the United States, and 2,000,000 cases of injury. These numbers have been considerably reduced of recent years, for the fatal accidents numbered 25,000 in 1913 and 22,000 in 1917, whilst the serious accidents were 700,000 and 500,000 respectively (Tolmann and Kendall).

However, a study of more recent American statistics shows that the tendency towards a reduced death-rate and the period 1912–1924 is not a marked one, for it is about 1 per cent. per annum, and the mortality rate due to accidents caused by machinery in industry has fallen by about 4 per cent. per annum.

Taking as basis the statistical returns for the State of New York, one is even forced to ask if the number of accidents has not increased, for though their number remained about the same for the years 1922–1923 and 1923–1924 (346,845 and 293,844), it increased considerably for the years 1922–1923 and 1923–1924 (346,845 and 371,708), an increase, that is to say, of 26 per cent. in two years. The number of fatal accidents increased for the same period by 60 per cent. (Hatch).

It is not always possible to find an explanation for the annual variations in the number of accidents reported for the various countries. The phenomenon is too complicated to admit of simple explanation. Resumption of industrial activity, increase in the number of employees, the introduction of compulsory notification of accidents, the more vigorous application of this measure, the application of the law regarding accidents to further occupational categories, the substitution of mechanical processes for manual processes, etc., are factors which, by themselves or in conjunction, may serve to explain the variation in the annual accident figures.

It is not even possible to draw general conclusions from the statistical data available, for though it may be said that in certain countries the number of accidents has a tendency to diminish (which, however, is not the case with regard to serious and fatal cases), in other countries, on the other hand, it is found that the figure for fatal accidents and permanent total disability has reached a fixed rate or has fallen, though there is an accompanying increase for temporary or partial permanent disability.

Since, further, the other factors have not varied, the first of these phenomena may doubtless be explained by the more extensive application of technical means of prevention. On the other hand, slight accidents which are more numerous, and the total of which constitutes a social loss of indissoluble value, are more frequently in proportion to the health conditions of the community and the conditions of the individual worker.

Statistical returns for certain countries provide the following figures:

In Austria, in 1923, 22,258 accidents, of which 185 were fatal, were reported, as against 22,443, 170 of which terminated fatally, in 1922.

In Belgium (for five districts which completed the requisite returns) there were 46,357 accidents, 211 being fatal, in 1923, as against 57,195, with 233 fatal, in 1922.

In Czechoslovakia the number of accidents mounted from 36,975 in 1923 to 47,021 in 1924. The construction of machines, metal founders, and the building industry showed the highest figures. The reports of the inspectors, however, emphasise the fact that the number of accidents is to be attributed to a resumption of industrial activity and to the increased personnel employed.

However that may be, it is nevertheless true that these accidents in their aggregate represent a sum total of pain and discomfort coupled with a temporary reduction of manual skill which is very large indeed.

In France, excepting the railways and mines, accidents in 1920 amounted to 658,350 with 1,932 fatal, in 1922 there were 682,830 with 1,857 fatal, and in 1923 777,975, 2,082 of which terminated fatally.

In Germany, in 1910, 484,097 cases of accidents were reported (5.16 per 100 insured), 5,292 of which terminated fatally (5.6 per 10,000 insured); in 1920 there were 433,049 accident cases (4.54 per 100 insured), 5,061 or 6.3 per 10,000 insured terminating fatally; in 1923, 346,950 cases (or 3.70 per 100), of which 5,243 (or 5.6 per 10,000 insured) resulted in death.

In Great Britain statistical returns for fatal accidents for the year 1924, for instance, are not comparable to those of the preceding years, because of the amendment to the Act passed in 1925. The increase in the total number of accidents is also to be in part attributed to the resumption of industrial activity.

In 1924 the total number of accidents was 169,723 as against 125,551 for 1923: 9,556 fatal accidents were reported as against 867 in 1923. In Great Britain there have been, during the last few years, about 1,200 fatal accidents per annum in factories and workshops, and another 1,200 in
coal mines and quarries, besides several hundred accidents on railways and elsewhere. Non-fatal accidents of sufficient severity to cause disablement for a week or more number about 120,000 a year in coal mines. In addition, there are about ten times this number of more trivial accidents which cause only a brief disablement, and often, indeed, involve only the time lost in putting on a bandage.

In Japan industrial factory accidents, which amounted to 48,582 (with 335 fatal) in 1913, did not exceed 32,973 (314 fatal) in 1921, and 31,314 (229 fatal) in 1922.

In the Netherlands there were, in 1922, 77,443 accidents, 151 of which were fatal, as compared with 78,490, with 167 fatal, in 1923.

In Sweden the number of accidents was 35,234 in 1922, with 223 fatal cases, and in 1923 41,996, with 239 fatal cases.

**Causes of Accidents**

To what extent are these accidents preventable? The word "accident" implies an event which takes place without one's foresight or expectation, and it follows that, if only this foresight is sufficiently clear and is adequately acted upon, there should be no accidents at all. Though it is impossible that such an ideal state of things as this will ever be attained in practice, there is no doubt that by taking suitable precautions the frequency of accident occurrence can be, and has been, enormously reduced in many instances, and actual figures in proof of this statement are quoted below.

In order to determine the most effective means of prevention, it is desirable to identify, so far as is possible, the various factors concerned in accident causation and roughly estimate the varying degrees of importance to be attached to them. Nearly all the factors are ultimately human in origin, but it is useful to draw a distinction between those which are due directly to the subject who suffers the accident, because of his own carelessness, lack of knowledge, or lack of skill, and those which are caused indirectly by his employer or someone else in authority because of the dangerous conditions under which he is compelled to carry on his work. Accidents due to unguarded machinery would fall into this class, although they form but a small proportion of the whole. Thus of the 162,154 factory and workshop accidents reported in Great Britain in 1918, only 53,491, or a third of the whole, were attributed to machinery, and not more than 35 per cent. of these machinery accidents were due to the absence of guards. Hence it was concluded that the provision of more adequate safeguards could not be expected to cause a reduction of more than 10 per cent. in the accident rate. Of the remaining 90 per cent. of accidents incurred it is supposed that practically all were due in greater or less degree to some failure on the part of the human subject involved, the result of carelessness and inattention, lack of proper appreciation of danger, or lack of skill. These factors will be discussed separately, so far as is possible, but they are usually bound up together so closely that it is impossible to disentangle them completely. More often than not an accident is due to the combined action of several factors, some of which may be acting in opposite directions, and it is difficult to obtain even a rough idea of their relative importance.

It was for long held that the causes accountable for almost all industrial accidents were connected with defective plant, insufficient safety devices and above all the so-called "carelessness" of the workers. Yet if statistics be carefully examined, demanding of course the most rigorous precision of these as well as general standardisation, the surprising result will be found that in Germany, for instance, the "unforeseen" factor being neither attributable to the worker or employer nor to the two together occurred in the proportion of 37-43 per cent. for the period 1887-1907, and in Norway it happened in as often as 90 per cent. of the cases from 1895 to 1906.

If a more detailed study of the statistics is made it will be seen, for instance, that out of 200,000 accidents assembled by the United States Steel Corporation 8.83 per cent. only related to machinery; that of the 4,969 accidents reported by the North Dakota Workmen's Compensation Bureau, and which occurred from 1920 to 1923, 12.6 per cent. only were caused by machines; that, according to German statistical returns, out of a total of 53,476 accidents which gave rise to permanent incapacity lasting at least thirteen weeks, 14,489, or 27.1 per cent., were due to machinery; that in Belgium and in France the same percentage was met with, whilst in Great Britain the so-called "negligence" of the worker was said to constitute the cause of the accident in 80 per cent. of the cases. Similarly in Italy, it was found that out of 1,000 accidents 200 were exclusively due to machinery, though the individual
factor also played a part in the accident, and the remaining 800 were caused by the human factor. According to a report dated 1924, the responsibility of the victims is said to have constituted an important factor in the production of 3,822 accidents reported in the Saar Basin. Of this number 254 were serious and 37 fatal.

The Human Factor

The development of social medicine has led specialists to a clearer study of the factors which play a part in accident causation, and whilst Imbert in 1905 drew attention to fatigue as one of the most important causes of industrial accidents, Pieraccini two years later brought to light other factors, such as the length of the working day, lack of rest during the day, etc. The factors giving rise to accidents can be classified as "external factors" and "individual" or "personal" factors. In the first group are included: the kind of work, the nature of the processes, the length of the working day, night work, arrangement of the working week, meteorological conditions, the area and cubic space allotted to each worker, the surrounding temperature, ventilation, lighting, the humidity, the speed of the work, the occupational risks pertaining to each class of work or operation, the wage, etc. Amongst personal factors should be classed the worker's origin (race, birth, etc.), his place of residence, age, education and training, length of service, physical, psychic, and endocrine constitution.

In this connection, the Americans have emphasised the importance, in regard to accident frequency, of newly arrived immigrants generally employed in the most trying and dangerous occupations. According to the Industrial Commission of Ohio, 50 per cent. of the fatal accidents affected this class of worker. It is evident that all accidents do not depend on the human factor. Of 2,678 accidents reported in Illinois in 1910, Bogardus found that 17.2 per cent. did not depend on the worker. Of 100 fatal accidents, Frois found that 25 were due to fortuitous circumstances impossible to foresee, 32 to insufficient protective measures, and 43 to faulty adaptation on the worker's part (lack of technical faculty 18, of physiological faculty 15, of psychological faculty 18).

If the phenomena connoted by the word "accident" be studied in accordance with modern scientific data, the conclusion is reached that accidents due to unforeseen causes impossible to forestall are very rare and that in nearly every case the true cause is the "man" himself, owing to some congenital lack of physical or psychological balance (it is now even permissible to talk of the lack of balance of the endocrine functions) or to such lack of balance deriving from intercurrent disease in a latent state of which the subject is but too often unaware himself.

The constitution, by its reaction on the nutritional exchanges, on the tonicity of the neurovegetative functions as well as on the hormonal type dominant in the individual on the one hand, and on the other the psychic temperament, which is in direct relation to the factors above referred to, exercises a remarkable influence on accident causation, on the evolution of lesions as well as on individual reactions, especially in regard to resumption of work and settlement of compensation (Biondi).

Hence arises the importance of the physio-psychic examination and of individual selection, on engaging workers, which has been prominently advocated in the United States, for instance. In fact an examination carried out with psychological tests proved that 70 per cent. of those examined had a childish mentality and that of these 15, or 31.5 per cent. of the total, were declared by the examiners to be incapable of self-control. It is, however, very difficult in practice to draw a hard demarcation line between accidents due to the human factor, accidents due to the mechanical factor, and those due to a combination of both these factors.

Sargent Florence classifies industrial accidents as follows:

1. Accidents due to unusual action of the material:
   (a) which no human capacity could have foreseen or escaped at the time;
   (b) which great attention might just have foreseen;
   (c) which through quick reaction might have been escaped;
   (d) which either by attention might have been foreseen or by quick reaction might have been escaped.

2. Accidents due to unusual action on the part of the worker owing to his lack of co-ordination or to positive inattention:
(a) extenuated by unusual conditions surrounding the work; 
(b) without such extenuation.

3. Accidents due to unusual action of material, due in turn to the injured man himself, e.g. shell dropped by man on his own toes.

It must be admitted that there exists in certain individuals impossibility of adaptation to their work as the result of physio-psychic reasons. It suffices to recall in support of this view the declaration recently made by Schridde of normal subjects:

Peri has classified as follows the causes of this impossibility of adaptation to a given kind of work:

- Constitutional weakness.
- Insufficient or inadequate feeding, especially in the case of people engaged on hard work.
- Internal diseases, diseases of nutrition or of toxic origin not however involving incapacity for work.
- Mutilation, effects of lesions, functional disturbances not however involving incapacity for work.
- Diminution in the function of certain organs (vision, hearing).
- Imperfection of muscular sense.
- Deficient intellectual faculties.
- Criminality.
- Abnormal states of conscience amongst neuropathic workers.

Special psychic moods in apparently normal subjects:

(a) difficulty in directing and maintaining the requisite attention; (b) imperfect mental lucidity due to slight intoxica
tion or as the result of serious chronic intoxication (especially alcoholism) amongst individuals not showing characteristic symptoms of chronic poisoning.

Individual predisposition to become easily fatigued or exhausted in course of work.

Various preoccupations not connected with work.

Inadequate estimate of danger inherent in the work: the worker becomes bold, imprudent, and negligent.

Exaggerated fear of accidents; the work is hindered and becomes tiring and dangerous for the individual and his fellow-workers; Insufficient sleep during the day (for the night shift workers).

The following gives a more detailed study of the factors just referred to.

**Diurnal Variations in Accident Frequency**

The frequency with which accidents occur from hour to hour during the course of the working day has been investigated in a large number of industries, and usually it is found that the variations show a considerable resemblance to one another. In the morning spell of work, which usually lasts four and a half or five hours, the accidents occurring in the first hour are comparatively infrequent. Other authors hold that accidents are relatively frequent in the first hour. In succeeding hours they rise rapidly till they reach a maximum in the last hour but one of the spell; whilst in the last hour they may fall off somewhat. This fall is due, partly or wholly, to the fact that the workers are apt to knock off work a few minutes before the end of the spell and make preparations for departure. Hence we are justified in saying that, having regard to the work done, the accident frequency tends to increase throughout the morning work spell, and it may be two to four times greater towards the end of the morning than it is at the beginning.

In the afternoon work spell it is more steady than in the morning, but usually it starts rather low in the first hour, works up to a maximum in the middle of the spell, and then falls off. It is often suggested that these variations of accident frequency are due chiefly to the fatigue incident to manual labour, for this fatigue must increase gradually during the course of work, whilst the fall of accident frequency which occurs between the end of the first work spell and the beginning of the next may be due to the recuperative effect of the meal hour.

Undoubtedly most industrial workers do get moderately fatigued by their daily round of work, but it appears that, as a rule, this fatigue is not sufficiently marked to account for more than a small fraction of the diurnal rise of accidents. This statement is substantiated by observing what happens to accident frequency when the workers are on night shift instead of on day shift. During the war there was plenty of opportunity for observing such shifts; and in the accompanying diagram are reproduced some of the results obtained by Vernon at a large
FUSE FACTORY OF 10,000 WORKERS. THESE RESULTS RELATE TO THE VERY NUMEROUS CUTS (USUALLY OF FINGERS AND THUMBS) WHICH WERE INCURRED BY THE WORKERS, AND TO THE LESS NUMEROUS EYE ACCIDENTS, DUE USUALLY TO SMALL METAL TURNINGS OR OTHER FOREIGN BODIES GETTING INTO THE EYE. IN THE STATISTICAL PERIODS STUDIED 13,251 OF THE FORMER ACCIDENTS OCCURRED AND 1,772 OF THE LATTER.

CONFINING ATTENTION FOR THE PRESENT TO THE YEARS 1916-1917, WHEN THE WORKERS PUT IN TWO 5-HOUR SPELLS OF WORK WHEN THEY WERE ON DAY SHIFT, AND THREE SPELLS, LASTING RESPECTIVELY 4½, 3½, AND 3 HOURS, WHEN THEY WERE ON NIGHT SHIFT, IT WILL BE SEEN THAT THE DAY SHIFT ACCIDENTS (CUTS) MORE OR LESS CONFORMED WITH THE PICTURE DRAWN ABOVE. THEY WERE AT A MINIMUM AT THE BEGINNING OF THE MORNING SPELL, AND RAPIDLY ROSE TILL THEY REACHED A MAXIMUM AT THE END OF IT. THEY DID, AS A MATTER OF FACT, FALL OFF DURING THE LAST FEW MINUTES, BUT IN THESE DATA THE ACCIDENTS OCCURRING DURING THE FIRST AND LAST QUARTER-OR HALF-HOUR OF EACH WORK SPELL HAVE BEEN IGNORED, BECAUSE THEY WERE INFLUENCED SO MUCH BY THE WORKERS NOT HAVING SETTLED DOWN PROPERLY TO WORK, OR BY THEIR HAVING CEASED TO WORK IN THE AFTERNOON WORK SPELL THE ACCIDENTS WERE MORE NUMEROUS THAN IN THE MORNING, AND THEY FIRST ROSE AND THEN FELL FOR THE MEN, THOUGH THEY FELL STEADILY FOR THE WOMEN. PASSING NOW TO THE NIGHT SHIFTS, IT WILL BE SEEN THAT, SO FAR FROM THE ACCIDENTS BEING AT A MINIMUM AT THE BEGINNING OF THE FIRST WORK SPELL, THEY WERE AT, OR NEAR, A MAXIMUM, AND THEN GRADUALLY FELL. THEY CONTINUED TO FALL FOR MOST OF THE NIGHT, AND IN THE LAST WORK SPELL THEY WERE ONLY TWO-THIRDS AS NUMEROUS AS IN THE FIRST WORK SPELL. THAT IS TO SAY, THE VERY SAME WORKERS WHEN THEY CHANGED FROM DAY SHIFT TO NIGHT SHIFT, SHOWED ALMOST A COMPLETE REVERSAL OF ACCIDENT FREQUENCY.

A SIMILAR RESULT WAS OBSERVED WITH OTHER GROUPS OF MUNITIONS WORKERS, BOTH IN ENGLAND AND IN AMERICA, AND THE EXPLANATION OF THE APPARENT CONTRADICTION IS PROBABLY TO BE FOUND IN THE PSYCHOLOGICAL STATE OF THE WORKERS. WHEN THEY CAME ON THE DAY SHIFT THEY WERE IN A DULL AND LETHARGIC CONDITION AS THEY HAD ONLY RECENTLY GOTTEN OUT OF BED, BUT THEY BRIGHTENED UP DURING THE COURSE OF THE MORNING AS THEY USUALLY HAD A CUP OF TEA AFTER TWO HOURS' WORK, AND THEY HAD THEIR DINNER BREAK TO LOOK FORWARD TO. CONSEQUENTLY, THEY BECAME MORE CARELESS AND INATTENTIVE, AND ACCIDENTS MULTIPLIED. THE NIGHT SHIFT, ON THE OTHER HAND, GOT UP THREE OR FOUR HOURS BEFORE THEY WERE DUE AT THE FACTORY, AND SPENT THESE HOURS IN RELAXATION AND AMUSEMENT, AND IN HAVING A SUBSTANTIAL MEAL. CONSEQUENTLY, THEY CAME TO THE FACTORY IN A LIVELY AND EXCITED STATE, AND THE CARELESSNESS THEREBY INDUCED CAUSED A MAXIMUM OF ACCIDENTS. THEY CALMED DOWN DURING THE COURSE OF THE NIGHT, AS THEY HAD NOTHING BUT BREAKFAST AND BED TO LOOK FORWARD TO, AND ACCIDENTS CONSEQUENTLY DIMINISHED.

IN STUDYING THE PRODUCTION CURVE OF WORKERS IN THE FACTORY ITSELF, PIERACCINI AND MAFFEI IN 1906 CAME TO THE CONCLUSION THAT THE FIRST STAGE OF THE WORK IS MORE UNCERTAIN AND LESS PROFITABLE THAN THE SECOND, DURING WHICH THE WORK ATTAINS AN EXCEPTIONALLY HIGH DEGREE REGARDED BOTH QUALITATIVELY AND QUANTITATIVELY AND THEREAFTER FOLLOWS A PERIOD OF HIGH AND STEADY PRODUCTION. THIS STATE, HOWEVER, SHOWS A PROGRESSIVE TENDENCY TO REDUCTION, AND WITH A CONTINUOUS SPELL OF WORK WITHOUT A REST INTERVAL IT LEADS MORE OR LESS RAPIDLY, ACCORDING TO THE TYPE AND RHYTHM OF THE WORK, TO A DETERIORATION IN THE QUALITY AND QUANTITY OF THE WORK ACCOMPLISHED.

EVIDENTLY GIVEN SIMILAR OBJECTIVE CONDITIONS — CONDITIONS OF RHYTHM AND OF WORK — THE ANTHROPOLOGICAL FACTOR PLAYS A HIGHLY IMPORTANT ROLE WHICH CANNOT BE IN GENERAL PRECISELY DEFINED. IT IS CERTAIN THAT PHYSIOLOGISTS AND HYGIENISTS SHOULD DEVOTE THEIR ATTENTION RATHER TO THE COST OF THE WORK TO THE SYSTEM THAN TO THE QUANTITY OF WORK WHICH THE ORGANISM IS CAPABLE OF ACCOMPLISHING. AN EQUAL QUANTITY OF USEFUL WORK REPRESENTS A VERY DIFFERENT EXPENDITURE OF ENERGY FOR DIFFERENT ORGANISMS (TREVES).

THE CURVE JUST REFERRED TO GIVES AN ACCURATE REPRODUCTION OF THE WEEKLY AND EVEN THE ANNUAL CURVE. IT, HOWEVER, SHOWS VERY MARKED SPECIAL FEATURES WHEN SEASONAL OCCUPATION OR RUSH WORK IS IN QUESTION.

THE FATIGUE FACTOR

THAT FATIGUE DOES NOT, AS A RULE, PLAY MUCH PART IN ACCIDENT CAUSATION IS WELL SHOWN BY COMPARING THE ACCIDENT FREQUENCY SHOWN IN THE DIAGRAM FOR THE YEAR 1915 WITH THAT IN 1916-1917. IN 1915 THE OPERATIVES WERE WORKING FOR 12 HOURS A DAY INSTEAD OF FOR 10 (I.E. FOR WORK SPELLS OF 5, 4½ AND 2½ HOURS' DURATION), AND IT WILL BE SEEN THAT THE MEN SUFFERED RATHER FEWER CUTS THAN THEY DID SUBSEQUENTLY, SO THEY CANNOT HAVE BEEN GREATLY FATIGUED BY THE EXCESSIVELY LONG HOURS OF WORK. WITH THE WOMEN IT WAS VERY DIFFERENT,
for the long hours threw them into a state of excessive fatigue. It will be seen from the diagram that though their accident frequency was about the same, for the first two hours, as that observed subsequently during the 10-hour working day, it rapidly mounted during the latter portion of the work spell, and on an average for the whole working day it was nearly three times greater than in the 10-hour day period. In men was very little affected. However, at a fuse factory in America it was found that men engaged in muscular work showed a greater increase of accidents as the day wore on than the machine workers, and this increase was presumably due to the fatigue entailed by the harder work. At the present day, when the hours of work seldom exceed 48 per week, the effect of fatigue on accident causation must be small in the great majority of industries. Undoubtedly extreme fatigue is a potent cause of accidents in men no less than in women, and striking instances of this are occasionally met with on the railways. Owing to unforeseen circumstances, a signalman or an engine-driver may have to work for an unduly long number of hours on end, and in consequence of his fatigue he may make a mistake which results in a terrible accident.

As an indication of the fatigue of the women, it may be mentioned that during the 12-hour day period they were treated for faintness at the factory surgery nine times more frequently than the men, whilst in the subsequent 10-hour day period they were treated only three times more frequently. Observations made at other factories confirmed the conclusion that whilst the accident frequency in women was increased by long working hours, that
**The Speed of Production Factor**

It is evident that accident frequency must be affected to some extent by the speed with which the articles are produced by the industrial worker. Each article may need the application of sharp tools, against which the hands or other parts of the body may be cut, and the more frequently the process is repeated the greater the risk.

Determinations of the hourly output during the course of the work spell generally show a relatively low output during the first hour, followed by a gradual rise which reaches a maximum towards the middle or end of the spell. For instance, the output curves recorded at the bottom of the above diagram, which represent the hourly output of the lathe and drill sections at the fuse factory during the years 1916 and 1917. During this time the rate at which certain typical articles were produced increased by 27 per cent. for the men and by 19 per cent. for the women, and at the same time the accident frequency increased by 48 and 14 per cent. respectively.

Modern scientific organisation is called on to revolutionise industry, to lead it towards a system of production superior to that followed at present; it must, however, take account of the “human factor”, for the speed of machinery, the sustained close attention demanded, and furthermore, the monotony of uniformly repeated operations characteristic of modern industry are all elements which tend towards wastage if not destruction of human energy.

**The Temperature and Ventilation Factors**

The degree of attention bestowed by a worker on his job is greatly influenced by the conditions under which he works, and atmospheric conditions are amongst the most important. Evidence on this point is troublesome to obtain, but during the war Osborne and Vernon regularly recorded the temperature at two large shell factories and at a fuse factory by means of the application of thermographs for a period of nine to twelve months. They found that the number of accidents (cuts) reached a minimum at a temperature of 18.3° to 20.6° C. (65° to 69° F.). At higher temperatures they rose rapidly, till at temperatures above 28.9° C. (75° F.) they were 23 per cent. more numerous than at the optimum temperature mentioned. This rise was presumably due to the workers getting more careless and inattentive during the hot weather, and confirmatory evidence of this hypothesis was obtained at a gold mine in Brazil. This mine (the Morro Velho) has reached the amazing depth of 6,400 feet, or 1½ miles, and it is, in fact, the deepest mine in the world. The working conditions were almost insupportable until a cooling plant was erected to cool down the intake air and thereby bring it towards a system of production that is superior to that followed at present; it must, however, take account of the monotony of uniformly repeated operations characteristic of modern industry are all elements which tend towards destruction of human energy.
numeros. There can be little doubt that this rapid increase of accidents at low temperatures was due to the workers losing some of their manual dexterity owing to the numbing of the fingers, for they were constantly handling shells and other metal objects.

The Lighting Factor

Accidents are often found to be considerably more numerous under conditions of artificial lighting than daylight. A Government enquiry into the lighting of factories was made in Great Britain, and it was found that on an average the accidents in a number of industries were 25 per cent. more numerous during hours of artificial lighting. Accidents due to "persons falling" were 75 per cent. more numerous, workers in docks showing an increase of no less than 120 per cent., whilst shipbuilders and ironfounders showed an increase of 99 per cent. In most industries it is found that night shift workers suffer more accidents than the day shift. In some steel works they were 16 per cent. more numerous on an average, but the workers in the yards showed an excess of 128 per cent., and those in the mechanical department one of 118 per cent. Probably this excess was due chiefly to defective lighting, for observations made in four large munition factories consistently showed fewer accidents by night than by day, the average difference being 17 per cent. However, the eye accidents were somewhat more numerous by night, those occurring in the least well lit factory being 41 per cent. in excess.

There can be no doubt that an adequate system of artificial lighting, even though it may be expensive to install, very soon pays for itself. Not only is accident frequency diminished, but there is an improvement of output which may amount to from 5 to 20 per cent.

The Experience and Age Factors

Inexperience is a very frequent cause of accidents, for it implies some lack of foresight and knowledge on the part of the worker and, in addition, a lack of manual skill and dexterity. Striking evidence was obtained by Chaney and Hanna concerning workers employed on stamping presses and other metal trade occupations. They found that on the first day of their work the operatives suffered 460 accidents, and in the next five days they suffered them at the rate of 83 per day. In the next three weeks the rate fell to 17 per day, and in the next five months to 5.2 a day. In the subsequent six months it fell to 1.8 per day, so the accidents were 235 times less frequent than at first. Data collected by Kitson and Campbell in factories where cutlery, railway-cars, and motor-cars were manufactured showed marked fluctuations of accident rate which corresponded closely with the numbers of new employees engaged; and it was concluded that if the labour turnover could be reduced to zero the number of accidents would probably be diminished by at least 75 per cent. As it is usually impossible to avoid some labour turnover, it would probably be worth while, from the economic point of view as well as on humanitarian grounds, to give new employees a preliminary week or two of training on fool-proof and dummy machines before they are put on to operate dangerous machinery.

Accident frequency continues to fall with increase of experience and age; at a large steel works, for instance, Chaney and Hanna found that whilst the employees had an accident frequency of 106 during their first year, the rate fell to 42 after four years' service, and to 9 after twelve years' service. Finally, the workers of over fifteen years' service suffered no accidents at all. This complete immunity is exceptional, especially considering the considerable number of men involved, namely, 37 affected workers employed for under six months, 14 workers employed for three to five years, and 3 only those employed for three to ten years.

However, though the accident frequency appears to diminish with the advance in the worker's age, the mortality and invalidity rates from accident increases with advanced age (Newbold). Newbold also found that though the accident frequency rate decreased with the advance in age of the worker and partly also with increase of experience, there was at similar ages no relation between the accident frequency rate and the amount of experience, whilst with a similar amount of experience the relation between the frequency rate and the worker's age was still maintained.

Recent statistics show that out of 54 accidents which occurred in a million working hours in the unhealthy trades 37 affected workers employed for under six months, 14 workers employed for three to five years, and 3 only those employed for three to ten years.

Even amongst operatives of the same age and experience the risks of accident are not equal. Thus Greenwood and Woods, in their observations on munition workers, found that some operatives were much more liable to suffer accidents than others who were employed...
on the same job. Apparently they possessed an innate clumsiness or carelessness.

In course of recent research, Newbold has shown that the average number of accidents amongst groups of workers was very markedly influenced by a relatively small number of workers who suffered from repeated accidents, and the distribution seemed far from being fortuitous. Certain workers are more subject to accidents than others, whether the cause may lie in varying working conditions, in the way in which the work is effected, or in the existence of a particular individual susceptibility which is besides persistently manifested by frequently recurring accidents at different periods, frequency of different types of accidents, frequently occurring accidents both in the factory and in the home. A closer study of such individual susceptibility calls for the application of psychological methods.

Accident frequency is similarly connected with slight indispositions attended to at dressing stations and first-aid posts, which again bear witness to the influence of the personal factor.

One of the factors which is of primary importance in accident causation is without doubt the course of employment. The accident rate rises and falls with the “up and down” of employment, the two corresponding closely in direction and duration. Increased employment brings increase of hazard growing out of the human element in accident causation (Hatch).

The Carelessness and Inattention Factors

No industrial worker can concentrate all his mental energies on his task for the whole of his working hours. His attention is bound to wander at times, and the more monotonous the task the more will his attention tend to scatter. In many types of industrial work such daydreams are harmless, for they may cause no reduction in the speed with which the task is performed and yet they will greatly diminish the feeling of boredom and monotony. When, however, the worker is employed on certain types of machinery, or is using sharp tools, carelessness and lack of attention may result in cuts to fingers and thumbs, or in more serious accidents. Hence it is necessary for him at almost all times to pay a certain amount of attention to the work in hand, though it is frequently found that he need not concentrate his mind fully upon it, except at certain critical periods.

Though the inattention of individual workers fluctuates a great deal from time to time, it is probable that, taking the workers as a group, their inattention tends to increase or decrease at certain times and under certain conditions, with consequent variations in their liability to accident. By studying these variations in accident frequency and the conditions which induce them much can be learned about accident causation and prevention.

Before, however, attributing an accident to carelessness or inattention it is necessary to make sure that other physio-pathological causes are excluded. The problem of accident causation is as complex as the human organism. Peri conducted, a few years ago, a very detailed enquiry in regard to a large total of accidents which occurred in a big Italian steel factory.

The frequency of accidents was found to affect those workers who lacked the requisite elements to ensure their physical integrity for instance (age, wages, experience, etc.).

The individual acquires adaptation to his task by learning the movements appropriate to its execution, forming special aptitude calculated to render such execution more perfect, and by avoiding all causes liable to harm his physical integrity.

Whilst the majority of workers forming the subject of Peri’s study had only had one or two accidents during four years, 393 workers had been ten to eleven times the victims of accidents. In fact, 2,338 workers had had 4,200 accidents or an average of 1.7 accidents per capita. These cases were distributed as follows (per 1,000 workers):

<table>
<thead>
<tr>
<th>No. of Accidents</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Workers</td>
<td>585.9</td>
<td>219.4</td>
<td>94.1</td>
<td>46.7</td>
<td>22.2</td>
<td>11.1</td>
<td>6.8</td>
<td>3.4</td>
<td>2.1</td>
<td>1.2</td>
<td>1</td>
</tr>
</tbody>
</table>

One worker had been eleven times the victim of an accident. It is necessary, therefore, to accept Peri’s theory that certain individuals find adaptation to a given type of work impossible. This impossibility of adaptation is not only personal, it may affect an entire family. Peri, in fact, has succeeded in assembling data affecting one family of ten members with sound constitutions and enjoying excellent health from a physical and psychic point of view, but who nevertheless in a period of four years of short spells of work had a total of 25
accidents, certain of which were fairly serious. Not one of the ten persons in question was able to retain his constitution unimpaired.

It is certainly difficult to arrive in every instance at the precise determination of the cause of an accident for in the majority of cases several causes play their part. Negligence is in many instances the source of violent injury, but when the medical man investigates carefully the facts leading up to the production of the accident in question, he very often discovers deep-seated agents other than mere carelessness on the part of the worker. It may be found, for example, that the cause of the accident has been the worker’s unwillingness to adopt certain means of protection provided (mask, glasses, etc.), a mistaken idea, a lack of appreciation of the risk involved.

After a certain length of service the worker is apt to neglect paying the same attention to his work as at first. His movements become automatic unconscious, especially where it is a case of machine work. Consciousness is not called into play or should only be called into play for giving the alarm. It is usual to find in a workshop a series of several accidents of the same nature occurring, the explanation being fear and uncertainty which spreads from the victim of the first accident to his companions. Work is spoilt, movements become uncertain and lacking in precision.

How many accidents, however, of which the victim is the involuntary cause are due to serious nerve troubles or to defective senses the presence of which are unknown to the individual in question? How many railway mechanics, for instance, have suffered from colour blindness or other visual defects caused by latent diabetes or the result of syphilitic infection which they imagined had healed? How many accidents have their origin in psychic epilepsy which is so hard to detect or in psychoneurosis, etc.?

Dupuy and Schiff after examining in 1925 the mental state of 36 taxi-drivers found that 35 suffered from serious neuro-pathological troubles, 12 from psychasthenia, 2 from manic-depression, 5 from epilepsy, 5 from chronic alcoholism, 5 from alcoholism with symptoms of dementia, 10 from general paralysis, etc.

Similarly as regards alcoholism the danger is not so much from workers who enter the factory slightly intoxicated as frequently happens after an unduly large meal, but from those workers who are in a chronic state of intoxication. It is such workers who constitute a real danger to themselves and others. Peri was able to collect data in relation to twenty-seven such workers who had met with 150 accidents; four of them had each had 12 accidents.

Undue indulgence in alcoholic liquors is a potent cause of industrial accidents, for it increases carelessness and inattention and may cause a reduction of manual skill. In a critical survey of available evidence, Voionmaa came to the conclusion that chronic alcoholism is a much more important cause of accidents than acute alcoholism. Persons medically certified as excessive drinkers have been found to be about three times more liable to accidents than other persons, and to injure themselves more seriously. Again, by merely controlling the sale of liquor in certain factories, or by stopping the supply of free beer, accident rates were decreased by 30 to 70 per cent.

Criminality is also a factor which should not be overlooked. It is not, however, possible to evolve general conclusions from the restricted data available. Peri nevertheless enquires whether it would not be of interest to study this aspect of the problem in detail in order to ascertain the existence of a possible relation between individuals incapable of adaptation to their social surroundings and those possessing a like incapacity as regards working conditions.

THE PREVENTION OF ACCIDENTS

The above discussion of accident causation has revealed a number of ways in which accident frequency may be reduced. Taking the evidence as a whole, it appears that by far the most fruitful method of eliminating accidents is to influence the physical state of the worker by diminishing his carelessness and inattention. The "Safety First" movement, which has spread so widely of recent years, depends fundamentally on the principle of cultivating what may be termed a "safety habit of mind" in the workers. To this end, it is necessary to take every possible opportunity of impressing on the workers the importance of observing precautions to avoid accidents.

The conclusion which can be drawn from what has just been said is that the problem of producing a general level of safety conditions high enough to prevent the rather paradoxical phenomenon of an increase in industrial accident hazards in times of rising business prosperity is mainly a problem...
of safety education rather than of mechanical safeguarding (Hatch).

To protect a machine by guards is not an extended process, and once done the machine stays safe so far as the purely mechanical element is concerned. But teaching good housekeeping and safe conduct in work places is a slow process of education both of workers and supervising authorities, and the results—stay put—only under continuous maintenance of teaching and morale of old employees, while with the advent of new employees the whole slow process has largely to be built again from the bottom, as it were.

In all prophylactic effort the main object is to understand the risk and be able to analyse it into its primary elements. Since a machine does not always and everywhere give rise to the same kind of accident, and the reaction of the individual to an injurious influence varies according to the personality of the subject, it is indispensable to have exact and detailed knowledge of each case in order to arrive at a scientifically established system of prevention. Precautions of a general character will never suffice in daily practice unless enforced in conjunction with a well organised system of social protection. For this reason Mr. Davis, Secretary to the Labour Department of the United States, recently (1925) demanded from Congress authority and an appropriate grant in order to assemble all available data concerning accidents and their prevention, for which purpose a statistical method on a uniform basis is required for this purpose is that the chem-

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Accumulators (Storage Batteries)


GENERAL REMARKS

The term "electric accumulator" is given to a galvanic element which, acting as a reversible cell, can accumulate electric energy. It owes this property to the fact that after running down it can be restored to its initial state by simply passing a current, the charging current, in the opposite direction to that of the current of discharge. The condition required for this purpose is that the chem-
ical reactions are similar, but reversed, during the two operations, discharging and charging.

It was the French physician Gautherot who noticed for the first time in 1801 the reversibility of cells. Plante made the discovery of the lead accumulator (1859), to which Faure in 1881 added important improvements.

Single accumulators are rarely used. As a general rule a number are grouped together in tension to form a battery of accumulators. Their uses are various and are extending from day to day.

This fact is due to two causes.

The first is that batteries can be used in a fixed position, for example, for motor-power in factories, for central lighting stations, for central telegraph and telephone offices, for scientific or industrial laboratories, or for workrooms for galvanoplastics; or can be quite easily carried about, for example, movable batteries for tramways, pleasure boats, submarines, and automobiles.

The second is that they have various uses. As accumulators properly so called they are used in electric traction on tramways, boats, automobiles, and railways, or in workshops or dwelling houses where their use is easy to supervise, which is not the case with dynamos or moving machinery. As transformers of electric energy the combinations to which they lend themselves in coupling allow the two factors of power from a given source to be varied at will, namely, the tension and the volume of the current, while at the same time the energy which they have accumulated can be stored for either a long or short period. As supply regulators in installations for continuous current, they serve to keep constant the factors of power from a source to which they are connected. Finally, as emergency aids they are installed to make good momentary defects in the irregular working of motor-generators.

In consideration of their many advantages and the ever increasing number of uses to which they are being put, electric accumulators have been the subject of numerous investigations in order to perfect and adapt them to required conditions by fresh modifications: and in this way a great variety of types has been invented.

From the special point of view in question in this article, namely, consideration of processes and dangers arising in their manufacture, accumulators may be divided into two main groups: first, lead accumulators, and, secondly, accumulators in which metals other than lead are used.

The second group do not exact much attention. As a matter of fact, accumulators which have not a lead base have up to the present, in spite of their interest, proved generally inferior to others and consequently their use remains very limited. This is all the more to be regretted in that their manufacture does not expose the workmen to lead poisonings, which, as will be seen, constitutes the chief danger in the manufacture of accumulators. It is to be hoped, then, that a type of accumulator of this second group may one day be evolved in a form in which it can be substituted for the first type. By way of example the following may be cited:

Gas accumulators with electrodes of platinum or palladium; these cannot be put to practical use owing to the extraordinary high price of the materials used.

Accumulators with an alkaline electrolyte, such as potash, in which the cathode consists of a thin plate of zinc, and the anode of oxide of copper or oxide of nickel: they present disadvantages owing to solubility of the metal of the cathode and of partial solubility of the anode.

Halogen accumulators use for the cathode an incorrodable metal, for the anode an incorrodable conducting substance, and for the electrolyte a metallic haloid salt, e.g. chloride of zinc, bromide of zinc, chloride of iron, chloride of bromium, or chloride of silver. But these accumulators are of inferior efficiency, or their price is too high.

Finally, there are accumulators with an unvarying electrolyte, in which the electrolyte does not take part in the reactions; they operate on discharge by oxidation at the cathode and reduction at the anode, and in charging by a reversed condition of things. A type of this variety has been applied to some industrial uses: this is the iron-potash-oxide of nickel accumulator of Jungner and Edison. It is used especially for movable batteries; it has the advantage of having electrodes that last longer than those of lead accumulators, but the disadvantage of being of higher net cost and entailing an additional expense in current, in consequence of the low output of energy.

**MANUFACTURE OF LEAD ACCUMULATORS**

An accumulator is essentially made up by electrodes set in a cell which encloses the electrolyte as well. Different accessories are added.

A description of the manufacture of the plates or electrodes, and of the other elements, as well as the putting together of the accumulator, will be considered successively.

First of all it must not be forgotten that formerly most makers each used a single type of plate which was supposed to respond to all uses. It is thus that a firm constructs several types of plate and elements, intended to be used for different purposes. However, the processes of manufacture, and especially the composition of the active materials, vary considerably from one make to another, and it is these peculiarities which have to be pointed out.
**Preparation of the Metal**

Lead intended for the making of accumulators is received at the factory either in the form of ingots or in that of old plates or disused scrap metal.

The utilisation of old plates and scrap metal require to be preceded by a process, the object of which is not only to ensure the melting of the grids, but also to effect the destruction, by reduction, of the oxides of lead which these elements may contain.

This operation is carried out in a reducing furnace, heated generally by coal.

The lead obtained is then run into the ingot moulds with a view to using it later on in combination with commercial metal.

In some factories the positive plates are treated mechanically in special apparatus, with a view to extracting, for commercial purposes, any peroxide of lead which they may contain.

**Manufacture of Plates**

Two varieties of lead plates are used for electrodes. One type of plate has a large surface; it is made of soft lead, and is characterised by the development of as large a surface as possible; the shape most commonly made has fairly strong horizontal ribs and fine vertical ribs close together. The second type of plate has renewable oxide; it is made of so-called unoxidisable lead, generally an alloy of lead and antimony, and has interstices which are subsequently filled with material in paste form. In this case the plate is in lattice-work, like a grid, with a simple frame surrounding a large lozenge of active material.

In order to obtain the plates, lead ingots are worked up either by the processes of casting, that is to say, at a temperature at least equal to that of melting, or by the low temperature process.

For casting plates, which is the process most commonly employed, lead ingots and old plates that can be re-used, are melted in cast iron pots at a temperature which should reach that at which pure lead melts, about 327°C. Then the metal is poured into steel or copper moulds, which are sometimes powdered with finely crushed steatite, and sometimes covered with lamp-black by means of acetylene jets. Each process has the disadvantage of discharging into the air either dust or smoke.

This work is done, sometimes by machinery, occasionally under pressure or in a vacuum with an exhaust, and sometimes by hand, which necessitates the moulder standing close to the melting pot in order to remove the dross and pour out the melted lead from a ladle.

The process at a low temperature is intended for obtaining, in the case of large surface plates, a development as extensive as possible and also a very homogeneous lead. Sometimes plates are made like lead tubes by thrusting the lead, brought to a malleable state by heat, through a die of the required shape. Sometimes a smooth plate of soft lead is taken and the surface is worked mechanically to produce fine active ribs by means of a Heimann machine, or that of Majert or by special milling tools.

After being made, plates must be submitted to accessory operations. Rough edges from the casting and seams are removed by means of files, scrapers, and iron-wire brushes. When the plates have been cast two at a time, they must be separated by a saw. Some are only supplied afterwards with the lugs for taking the current and suspension hooks; these parts are fixed by autogenous welding.

The plates of the second category, i.e. plates of the Faure kind, or those filled with active material, must be completed after making by the addition of a mixture called paste.

The pastes are of different composition depending on the requirements. They have as their basis either oxides of lead (litharge, minium, or a mixture of them); or, more rarely, pulverised lead, obtained by projecting a strong current of hot air on to a fine jet of melted lead; or, yet again, a salt of lead, usually chloride of lead, used in the softened or melted state. To these are added either substances designated as binders whose rôle is to cement the mass and to make it mechanically sufficiently resisting, or other substances which are removed after the pasting and leave the mass more porous. Whatever paste may be used it generally has for a base sulphuric acid, and it is owing to the sulphuric acid that the material consolidates and hardens, in consequence of the formation of lead sulphate in the mass. Sometimes the oxides are worked up first with water, and it is only after the pasting that the plates are soaked in the acid. Sulphuric acid can also be replaced entirely or partially by alkaline sulphates or alkaline earths. As agglutinating substances the following are freely used: phenol dissolved in water (especially in the case of
plates with frames), glycerine, glue, and ammonia.

The materials which are used in the preparation of the paste are received as powder, dry or mixed with liquid, and are weighed, mixed and blended under very different conditions according to the factories. Sometimes the mixing and blending is done in a hermetically closed apparatus; sometimes the materials are emptied into an enclosed space where they are weighed and mixed by a workman who stands outside and carries out these operations through an opening made in the side of the protecting box; sometimes the work is done in glass receptacles connected with a large chimney used for an exhaust draught; sometimes the weighing, mixing and kneading is done in the open air on ordinary scales in open apparatus; sometimes even without any exhaust arrangement and without any protecting apparatus.

In order to use the paste, that is to say, in dressing the plate with active material there are two quite distinct processes.

The first, which is more usual, consists in introducing active material into the prepared frame, that is to say, into the spaces of lattice work. This operation is often used in which the plate is arranged in position, the melted lead being poured on the plate. Sometimes the work is done in a glass spatula or the palm of the hand, or mechanically; sometimes by means of a hydraulic press.

The second method consists in making lozenges of active material around which, after they have been arranged in position, the melted lead is run to form a lattice pattern. This method is used particularly when the active material can be moulded into lozenges at a higher melting point than that of lead, as is the case with chloride of lead. With it the reverse process cannot take place, for chloride of lead cannot be cast into a lattice-patterned plate since lead melts at a lower temperature.

Pasters work under quite different conditions in different factories. Their work-benches may or may not be supplied with exhaust draughts. These work-benches are sometimes made entirely of wood; they then become impregnated with lead dust and cannot be thoroughly cleaned. Tables covered with plate glass are preferable, especially when a wooden edge prevents dust from the paste and debris from falling on the floor.

After pasting, the plates must be dried. This operation is done either in the actual workshop where the pasting is done or in special rooms, or in a stove. Sometimes, to speed up the drying, after the pasting, strips of paper are put on the plates and these are subsequently torn off and often actually thrown on the ground of the workshops.

Finally they are scraped, brushed and polished with the special object of freeing their edges and points of connection from irregularities of active material, which work is carried out mechanically or by hand.

Both types of plates, plates with large surfaces and plates charged with active material, must be subjected before being put into use to an electric treatment known as "forming" (first charging), which consists essentially in exposing them for a sufficient time to the action of an electric current which gives them their definite chemical composition.

This is an extremely delicate operation.

In the case of pasted plates, the first charge has for its object the transfer of them into peroxide if they are positive, and if negative into spongy lead. It simply consists of one charge in weak sulphuric acid or in an alkaline sulphate, the plate being put as anode in the first case, and as cathode in the second. When the paste has been prepared with chloride of lead, formation consists in a reduction of the salt into spongy lead, a reduction which can be effected by putting the plates to be reduced in contact with sheets of zinc.

For plates with large surfaces the method usually adopted consists in producing the active material at the expense of the soft lead of which the plate is composed; one part of this soft lead is transformed either into peroxide or into spongy lead, whilst the resisting part acts as support and conductor. This is autogenous formation in opposition to the heterogeneous formation of pasted plates.

Different processes are employed for autogenous formation. Planté formation is often used in which the plate is subjected to successive periods of charge and discharge, with a reversal of the direction from time to time; this method has the disadvantage of being long and costly. Electro-chemical formation only requires a charge in one direction, in order to cause sufficiently deep peroxidation of the active soft lead; it is obtained by the addition of sulphuric acid to different substances: either to nitric acid or alkaline nitrates or to organic acids, or to chlorates, bichromates, permanganates, etc. It is necessary there-
after to remove completely from the prepared plate all trace of added material which may be injurious to its preservation: this is done by washing in appropriate solutions. Formation by purely chemical action, such as by nitric acid, or by electrolytic deposit obtained by decomposition of a lead salt, are two methods very little used.

Mounting Lead Accumulators

The plates, or electrodes, as well as the electrolyte, are brought together by means of different accessories and joined up to make the accumulator. The most important of the accessories is the receptacle which holds the parts. Its principal quality is to resist attack by sulphuric acid, which condition very much limits the choice of substances which can be used to such things as glass, ebonite, celluloid, lead, and gummitite. Glass is used if the cells are of small or medium dimensions and the batteries are fixed in position; ebonite and celluloid are used for transportable batteries; lead for batteries in fixed positions. These last are generally made of a case of wood with a lining of lead; more rarely they are entirely of lead containing antimony. Ebonite cells are those most used in transportable batteries. Celluloid is only used when there is no danger from sparks which might set it on fire. Celluloid has the advantage of being very easily stuck together by special glues obtained by dissolving celluloid in acetone or acetate of amyl.

The connecting up of plates of the same polarity must be made, secure with bolts or autogenous welding; this latter is done electrically or by a hydrogen blowpipe. The men who do this welding or burning proceed in different ways. Sometimes they bring together the ends of the plates and a lead cap, upon which the blowpipe is directed, and, in order not to diminish the thickness of the metal where the burning is done, the worker holds in the other hand a stick of lead, from the extremity of which, as it melts, drops fall on to the parts already in apposition. Sometimes the ends of the plates are arranged in a special mould into which very hot lead from a ladle is poured.

The plates are arranged vertically in the cells which are filled with acid; they rest on grooved bars or are suspended by hooks, and are separated one from another by rods or sheets of glass, wood, ebonite or celluloid, or by porous sheets of wood, peat, porous earth, etc. The plates are then fixed to the cover of the accumulator and to the external connections. This last operation again requires lead burning.

Sources of Danger

The above technical details show that workmen are exposed to many troubles and numerous dangers in the course of the manufacture of accumulators. The most common and most serious arise, according to all evidence, from the handling of lead, and of its oxides and salts. Experts in different countries are all of opinion that this industry is to-day the one which causes the greatest number of cases of lead poisoning.

Risk of Lead Poisoning

It may be said that all operations required for the manufacture of lead accumulators expose the workmen to this serious poisoning, either by direct contact with lead and its compounds or by the inhalation of lead fumes and dust.

In one factory the dust collected in the yard contained 40 per cent. by weight of metallic lead. The proportion was 12 per cent. outside the premises in front of the entrance gate. Inside the workshops on account of frequent cleaning, this proportion is decidedly less, but still quite appreciable. In one workshop where plate-casting is done, the dust contained 0.2 per cent. of lead on the ground and 0.1 per cent. at a height of one to two metres above the ground (Agasse-LaFont). A primary risk occurs at the very moment when the metal and its alloys are prepared, that is to say, during the manipulation of new ingots or old plates; in the course of analysis undertaken to determine the exact quality of the ingots used; during the charging of the reducing furnace; during the casting of the metal in ingot moulds; during the collection of the slag drawn off from the reducing furnace after casting. This last operation, although done in the open air, is a source of lead-laden dust. In the course of an enquiry, an estimation was carried out in the open air, in the vicinity of workmen carrying on charging, by Heim de Balsac, Agasse-LaFont, Feil and Pouilbot, who observed the presence of 0.0002 gm. of lead per cubic metre of air.
The work of casting and moulding plates brings the workman into contact with fumes and dust. It has undoubtedly been maintained that melted lead in the cauldrons should be below the evaporating point. But it has been proved that fumes come off when the lead reaches 450° C. Moreover the extreme thinness of certain parts of accumulator plates makes it necessary for casting that the alloy should reach a high temperature which in practice frequently reaches 700° C. The evolution of lead fumes is greatly facilitated by this high temperature.

Various samples and estimations made in plate foundries by the above-mentioned experts gave the following results:

**Plate Foundry**:

- **(a) Sample taken under ventilating hood**:  
  - Fumes per cubic metre of air: 0.0024 grm.  
  - Dust: 0.00025 grm.  
  - Total: 0.00065 grm.

- **(b) Sample taken outside ventilating hood**:  
  - First test:  
    - Fumes per cubic metre of air: 0.0012 grm.  
    - Dust: 0.000768 grm.  
    - Total: 0.001988 grm.  
  - Second test:  
    - Fumes per cubic metre of air: Traces.  
    - Dust: 0.0004 grm.

In the first test the melting pots were supplied with ventilating hoods in which the exhaust was clearly insufficient. In the same workshop at a distance of about six metres from the melting pots, the presence of 0.0007 grm. of lead fumes per cubic metre of air was also found.

**Foundry for Accessories**:

- **Fumes per cubic metre of air**: 0.00047 grm.  
- **Dust**: 0.000082 grm.  
- **Total**: 0.000552 grm.

Often after having skimmed the melting pots the moulder throws the dross on to the floor, where it is trampled on and reduced to dust, which spreads into the air. The danger varies in the melting shop according as to whether suitable precautions are taken or not, to whether the number of melting pots is greater or less, and to whether exhaust installation is used or not.

Operations, which are auxiliary to the work at the foundry, such as scraping and brushing the plates, and soldering the attachments, also give rise to dust and lead fumes. At the level of the face of a workwoman, whose work was to do the scraping, the authors quoted found 0.0012 grm. of lead per cubic metre of air. The extent of the danger from burning is variously estimated; by some it is regarded as one of the most dangerous operations; by others, on the contrary, it is held to be less harmful than pasting and other operations in which dry oxides are used. Nevertheless it happens that burning may be carried on in the same place as melting, when the burners are exposed, in addition, to danger from fumes arising from melting pots.

For certain plates the formation of grooves and ribs is done by machines, the plates being kept cool by means of oil and water. Although this method eliminates fumes and dust, direct contact with the metal, which may soil the hands, offers some danger if attention is not paid to the cleanliness necessary.

Pasting and smearing (tartinage) the plates, which are preceded by the preparation of the paste or the mixing of the oxides, litharge and minium, are two equally dangerous processes.

The preparation of the paste deals with the oxides of lead in a pulverised state. This operation is usually done by hand, and there is no doubt but that it gives rise to the liberation of lead dust, which is all the more dangerous from the fact that it is produced at the breathing level of whoever has to carry on the work.

On the other hand, this dust appears to fall again very rapidly on to the ground on account of its density. Some tests made in a place used for the preparation of paste gave these results:

- **(a) Before the operation of weighing and mixing the oxides of lead**: traces which could not be estimated.
- **(b) During the weighing and mixing of the oxides**: 0.0018 grm. of lead per cubic metre of air.
- **(c) During wet mixing**: traces.

Sometimes the workman, to prevent the paste from sticking, throws handfuls of dry litharge on to the tray where the mixing is done; this proceeding increases considerably the amount of dust.

In the operation of smearing the materials are used in the state of paste; there is then little to fear from dust in the course of the operation. Nevertheless fragments of paste remain stuck to the worktable, where they dry and, combined with the handling of the plates, can lead to the generation of dust. At the workplace of a man employed on smearing, 0.0012 grm. of
lead dust per cubic metre of air was found.

The facing of the plates with lead powder is a particularly dusty operation.

The drying of plates in stoves necessitates the workman entering these places, where the temperature may reach 80° C., in order to put in or take out the plates. In one factory some samples of air taken in a drying stove while in use gave the following results:

<table>
<thead>
<tr>
<th>Temperature of the stove</th>
<th>Fumes of lead per cubic metre of air</th>
<th>Dust</th>
</tr>
</thead>
<tbody>
<tr>
<td>75° C.</td>
<td>0.001 grm.</td>
<td>0.00008 grm.</td>
</tr>
<tr>
<td>Total</td>
<td>0.00108 grm.</td>
<td></td>
</tr>
</tbody>
</table>

The formation (first charging) of plates does not give rise to any dust. Apart from contact of workers' hands with lead, a point which will be referred to later, the conditions of hygiene and safety in workshops in which formation is done are of the same kind as are observed in the rooms where accumulators are in use.

Burning of the connections on the finished plates must receive attention. For one thing the temperature required to assure autogenous burning of the various parts may cause the emission of lead fumes, and then also the handling of dry plates may facilitate the deposit on the worktables of particles detached from the spaces and capable of giving rise to dust.

Some tests carried out in Germany, which consisted in suspending a moistened filter paper above a blowpipe, have shown that volatilisation of lead occurs with the oxyhydrogen flame (see also questions "Lead" and "Oxidising").

According to Hamilton, the operations in the manufacture of accumulators may be classified from the viewpoint of risk of industrial lead poisoning as follows: mixing, pasting, assembling, and soldering. Much less dangerous are the operations of melting and trimming. According to Drancourt (France, 1904) those most affected were the men employed in mixing, next in order those who cast the electrodes, those who did the sawing and the trimmers. English statistics give a table of figures of which show the gradation of risk of lead poisoning in this industry.

It is stated that in the United States a mixture of hydrogen and air is used for burning, whilst in other countries the oxyhydrogen flame is used which is hotter and in consequence liable to produce greater volatilisation of lead.

Besides, from the fact that a large number of other operations are carried on in the burning workshop, it is generally difficult to estimate exactly the quantity of lead volatilised or to determine in what measure the poisoning of burners is due to the generation of dust or the volatilisation of lead.

Scraping, brushing, and polishing of the attachments and edges of plates, operations which complete the preparation of certain elements, set free a good deal of dust. Done by hand and without an exhaust they would be very dangerous. On the other hand, when done by means of mechanical brushes fitted with an exhaust they seem to be hardly injurious at all. A sample of air from a workshop in which this work was done gave a negative result from the point of view of the presence of lead. But the presence of 0.0026 grm. of lead per cubic metre of air found at the exit of the ventilator, in spite of the great volume of air evacuated and the presence of a drum of water intended to arrest the dust, showed the danger with which this operation would be accompanied if the dust were not evacuated and carried off as quickly as it is produced (Heim de Balsac, Agasse-Lafont, Feli, and Pouillot).

Finishing, which necessitates lead burning by means of the oxyhydrogen flame in order to fix the electrodes to the lid of the accumulator and to external connections, involves dangers which have already been pointed out.

It is the same as regards the construction of cells of large dimensions, made of wood lined inside with sheets of lead, the edges of which must be soldered together. During this work the workman is obliged to put his head inside the box in order to make sure the joints are good and will not allow liquid to leak.

An enquiry made by the principal chemist of the English Government to determine the quantity of lead fumes and dust set free in the accumulator industry gives the following rates:

<table>
<thead>
<tr>
<th>Number of tests</th>
<th>Duration of test in hours</th>
<th>Number of cubic feet of air aspirated</th>
<th>Quantity of lead in aspirating apparatus, grm.</th>
<th>Weight of sample in grm.</th>
<th>Percentage of lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>176</td>
<td>0.00170</td>
<td>1.4870</td>
<td>6.27</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>194</td>
<td>0.00258</td>
<td>0.0170</td>
<td>22.90</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>187</td>
<td>0.00404</td>
<td>(0.00517)</td>
<td>(0.00244)</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>163</td>
<td>0.00371</td>
<td>(0.00402)</td>
<td>(0.00251)</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>190</td>
<td>0.00170</td>
<td>0.0200</td>
<td>9.11</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>194</td>
<td>0.00104</td>
<td>0.0240</td>
<td>12.87</td>
</tr>
</tbody>
</table>
In order to interpret accurately these figures it is necessary to take into account the observations made by the medical inspector in his report for 1908 (pages 119-120).

The presence and quantity of lead and lead fumes have been demonstrated not only in the air of workshops, but also in the nasal cavities and on the hands of workmen.

The French experts already quoted have collected dust, by swabbing the nasal fossae with a swab of absorbent wool, of which the lead content was found to be as follows:

<table>
<thead>
<tr>
<th>Kind of employment</th>
<th>Quantity of lead (in grns.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fountry (man)</td>
<td>0.000007</td>
</tr>
<tr>
<td>Fountry (woman)</td>
<td>0.000018</td>
</tr>
<tr>
<td>Trimming (man)</td>
<td>0.000008</td>
</tr>
<tr>
<td>Preparation of paste (man)</td>
<td>0.000080</td>
</tr>
<tr>
<td>Preparation of paste (woman)</td>
<td>0.000080</td>
</tr>
<tr>
<td>Pasting (man)</td>
<td>0.000006</td>
</tr>
<tr>
<td>Pasting (woman)</td>
<td>0.000000</td>
</tr>
<tr>
<td>Formation (man)</td>
<td>Traces</td>
</tr>
<tr>
<td>Formation (woman)</td>
<td></td>
</tr>
<tr>
<td>Brushing (man)</td>
<td>0.000002</td>
</tr>
<tr>
<td>Management (man)</td>
<td>Indeterminable traces</td>
</tr>
</tbody>
</table>

Other Sources of Danger

Although less important and only affecting a group of workmen here and there, a number of other causes of industrial ill-health due to the manufacture of accumulators should at least be enumerated.

First comes the inhalation of sulphuric acid fumes. This danger exists particularly at the time of first charging, the bubbles which then rise carrying with them drops of acid.

The action of these acid fumes has been the object of several enquiries. The acid droplets which are suspended in the atmosphere irritate the mucous membrane and, without doubt, cause a certain number of cases of irritation, but serious injury to the respiratory passages is not known. Bottrich (1916) has even affirmed that these acid fumes exercise a favourable action on the system, which is denied by Chyzer, who found, in 1908, that the quantity of acid deposited on 1 m. of surface can be estimated at 1.28 grm. (with open windows) and even at 2.97 grm. (with closed windows). Rambousek attributed dental lesions found among workmen in this industry to these fumes. However, regrettable consequences, such as bronchitis and epistaxis, are to-day doubted by most experts.

The irritating action of sulphur dioxide has also been pointed out among persons employed in the formation department.

Inhalation of ammoniacal vapours occurs when preparing the paste; most of the liquids used for moistening contain a variable proportion. In a place used for preparing paste 0.35 grm. of ammonia gas (N H) per cubic metre of air was found.

The use of illuminating gas or coal, particularly during casting with the use of compressed air, introduces a risk of carbon monoxide poisoning. The use of autogenous solder may cause the injuries described in the article "Soldering".

Mercury is used in the state of an amalgam, since, in order to avoid corrosion of zinc electrodes, they are dipped in a solution of mercury in nitric or nitro-hydrochloric acid. Attention has been drawn to several cases of mercurial poisoning by Teleky. A mixture of lead and mercury for soldering has also been used, especially during the war. During this operation mercurial fumes are set free, which have given rise to several cases of subacute mercurial poisoning (Devoto, etc). Sublimate, about 30 grm. per kilogram of metal, is also used for dry batteries.

The possible presence of arsenic in lead ingots is considered as the cause of arsenical poisoning by some authors. But if this ever occurs it must be rare, for it appears that lead containing arsenic would not be suitable for making accumulators.

Kober and Hayhurst mention some cases of poisoning by arseniuretted hydrogen.

The manufacture of small cells for portable accumulators by means of
celluloid compels men or women to handle celluloid powder, which is very inflammable and gives off a strong smell of camphor; and also a cement in the preparation of which is kept secret and which gives off a tart, acridulated smell, rather like that of English acid drops. Without knowing its exact composition, it is made up chiefly of a mixture of acetate of amyl and acetone (Zapon lacquer).

An investigation made by Heim, Agasse-Lafont, and Feil among workmen employed on this work led to the following observations:

Cephalalgia seemed to constitute the only clinical symptom: it was especially acute in the early days of employment before the workwomen had become accustomed to the smell of the camphor; later, when they were inured to it, the headaches were slighter and even completely disappeared in many cases.

Examination of the blood showed eosinophilia five times out of a total of eight sick persons examined: the eosinophilia was equal to, or above, 4 per cent.; like the cephalalgia, it must be attributed to the effect of the poisonous substances used.

It is probable, without it being possible to bring certain proof, that the cephalalgia is attributable to camphor fumes which seem particularly to trouble the patients.

Eosinophilia must rather depend on the action of acetone and acetate of amyl on the blood.

Finally, as rarer manifestations and of less importance, attention should be drawn to pneumoconiosis, caused by the inhalation of the various dusts and in particular of talc used frequently in the foundry (0.6 grm. per cubic metre has been found in the atmosphere of a workshop); to trade eczematous dermatitis, from the use of gum arabic and rectified spirit for the making of insulating plates in mica; to burns, from melted lead or acids; to eye troubles, from the action of ultra-violet rays which certain methods of heating emit; to brassfounders’ ague, when there is in the factory a department making brass objects (Kober); and to electric accidents, from discharge among those who test apparatus.

During the manufacture of dry batteries, workmen are required to handle benzoil, sulphuric acid, phenol, pitch, chloride of zinc, and mercury.

Attention must be specially drawn to cutaneous lesions, which are quite frequent and generally are due to the irritating action of these products. Rare and even doubtful are cases of cancer of the skin described among these workmen, which some would attribute to the action either of coal dust or the chemical products handled.

**STATISTICS**

In Germany the statistics which are available are rather out of date. Those of Wagener (1902) deal with a factory (unknown) in which cases of sickness occurred at the following rates among the workmen of different classes: casters, 10 per cent.; burners, 37.5 per cent.; pasters, 30 per cent.; mounters, 0.3 per cent. It is curious to notice that the expert in question emphasised the rarity of lead poisoning in this factory.

In Prussia, 28 cases were noted (out of a total of 619 cases of lead poisoning), in 1910, 26 in 1911 (total 738), 17 in 1912 (total 1,119).

In 1913 an enquiry made by Schultze enabled him to report that the hygienic and sanitary conditions in the factories visited, and even in the small factories, were good.

Yet according to the reports of inspectors it is stated that at Berlin in a factory employing 1,100 workmen, 40 cases were reported in 1920 with a duration varying from one to three weeks; in 1921, still at Berlin, 29 cases of lead poisoning were reported from accumulator factories out of a total of 48 cases of lead poisoning. Of these 29 cases, 18 were pasters, 6 casters, and 3 formers. In 1922 a factory reported 45 cases against 25 in 1921. Generally it was the unskilled workmen who were affected.

In Austria during an enquiry made in 1921 by the factory inspectorate in an accumulator factory, all the workmen much exposed to risk of lead poisoning showed marked signs of lead absorption.

Some States of the United States of America furnish us with statistics on the frequency of lead poisoning in the accumulator industry. In the State of Illinois, for example, from 1 July 1920 to 30 June 1922, out of 318 cases of lead poisoning reported, 29 occurred among workmen in accumulator factories.

During his enquiry in the State of Ohio, Hayhurst visited nine accumulator factories and reported employment on a large scale of untrained workmen, ignorant of the simplest hygienic measures. He also noticed that methods for carrying off dust, vapours, and poisonous fumes did not exist or were inadequate, which explained the very large number of workmen affected with lead poisoning. According to Hayhurst the manufacture of accumulators is the industry in which causes the greatest number of cases of lead poisoning, after that of the oxides and salts of lead. The same conclusions have been drawn from an enquiry into dry-battery factories. From 1 July 1920 to 30 June 1925, out of 443 cases of lead poisoning, 145 had been observed in accumulator factories.

In the State of New York from 1912 to 1925, 722 cases of lead poisoning were
notified, of which 152 were from accumulator factories. The enquiry of Hamilton (1914), dealing with the most important factories of the United States, which was repeated in 1918, also brought to light some interesting figures, showing that five factories employing (during the previous year) 915 workmen had notified 164 cases (17.9 per cent.) of lead poisoning. Moreover, the work was generally — according to Hamilton — such as did not require any special qualification on the part of the workman, who also received very poor wages. In consequence the changes in personnel (labour turnover) were very great. Cases of lead poisoning occurred after quite a brief exposure to the poison: in 3 cases after less than a month's work, in 41 before six months, and in only 7 (out of 70) after a year's employment. Statistics arranged by categories were as follows:

<table>
<thead>
<tr>
<th>Category</th>
<th>Persons employed</th>
<th>Number of cases of lead poisoning</th>
<th>Per 100 persons employed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casters</td>
<td>177</td>
<td>3</td>
<td>1.7</td>
</tr>
<tr>
<td>Mixers, fillers</td>
<td>26</td>
<td>8</td>
<td>30.0</td>
</tr>
<tr>
<td>Pasters of plates</td>
<td>160</td>
<td>31</td>
<td>19.4</td>
</tr>
<tr>
<td>Assemblers, burners</td>
<td>282</td>
<td>28</td>
<td>10.7</td>
</tr>
<tr>
<td>Total</td>
<td>619</td>
<td>70</td>
<td>11.3</td>
</tr>
</tbody>
</table>

Generally, the illness takes the form of lead colic. In 40 cases, closely studied, there were noticed colic 24 times, abdominal pains 9 times, intestinal trouble 7 times, marked anaemia 22 times, constipation 27 times, diarrhoea 3 times, muscular pains 7 times, vomiting 7 times, headache 9 times, persistent nausea 4 times, nervous symptoms 23 times of which there were 3 cases of paresis, 4 cases of paresis of the hand, 1 case of delirium, and 1 case of epileptic convulsions.

In France as early as 1904 Drancourt, an inspector of factories, drew attention to danger of lead poisoning in the accumulator factories of the Department of the Seine. Those most affected were workmen employed on mixing, and those who cast the electrodes, the cutters and trimmers.

The application of compensation legislation to lead poisoning enables the following figures to be given: in 1921 there were 18 cases in the accumulator industry out of 144 cases of lead poisoning (12.5 per cent.); in 1922, 180 cases out of a total of 797 (22.58 per cent.); in 1923, 250 out of 1,025 (24.29 per cent.); and in 1924, 250 out of 1,343 (31.79 per cent.).

Two recent investigations by Heim de Balsac, Agasse-Lafont, and Feil give an idea of the danger which threatens these workmen, varying with the nature of their work. A group of 50 workmen employed on various kinds of work gave the following figures which relate to clinical and haematological indications of lead poisoning as well as the number of acute attacks:

<table>
<thead>
<tr>
<th>Classification</th>
<th>Persons employed</th>
<th>Number of cases of lead poisoning</th>
<th>Per 100 persons employed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smealers and pasters</td>
<td>9 (81 %)</td>
<td>14 (157 %)</td>
<td>10 (9 %)</td>
</tr>
<tr>
<td>Mixers</td>
<td>0</td>
<td>3 (36 %)</td>
<td>0</td>
</tr>
<tr>
<td>Handling of plates</td>
<td>10 (91 %)</td>
<td>9 (64 %)</td>
<td>8 (80 %)</td>
</tr>
<tr>
<td>Burners</td>
<td>0</td>
<td>0 (0 %)</td>
<td>8 (80 %)</td>
</tr>
<tr>
<td>Repairing</td>
<td>0</td>
<td>0 (0 %)</td>
<td>0</td>
</tr>
<tr>
<td>Trimming (females)</td>
<td>0</td>
<td>0 (0 %)</td>
<td>0</td>
</tr>
<tr>
<td>Chief checker</td>
<td>0</td>
<td>0 (0 %)</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>14 (87 %)</td>
<td>10 (65 %)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Classification</th>
<th>Persons employed</th>
<th>Number of cases of lead poisoning</th>
<th>Per 100 persons employed</th>
</tr>
</thead>
<tbody>
<tr>
<td>French</td>
<td>9 (26 %)</td>
<td>9 (19 %)</td>
<td>8 (80 %)</td>
</tr>
<tr>
<td>Moroccans</td>
<td>21 (74 %)</td>
<td>15 (71 %)</td>
<td>7 (30 %)</td>
</tr>
</tbody>
</table>

These investigations have led to the following conclusions:

(1) Workmen employed in the manufacture of accumulators show a very high percentage of symptoms and acute attacks of lead poisoning which far exceeds that found in other lead industries.

(2) It is among smeealers (tartineurs) and pasters, and also the mixers, that indications of lead absorption most frequently occur. This group especially needs medical supervision.

(3) Among haematological indications, in addition to the very frequent presence of red blood cells with basophilic granules, a condition almost pathognomonic of lead poisoning, the importance of which is today well known, there are sometimes found nucleated red cells (normoblasts). It is also quite characteristic for the blood in lead poisoning to include these elements apart from any serious anaemia. Experimentally this fact has been for a long time fully established. 1

1 According to some experts (Biondi, for example) the presence of normoblasts in the blood of cases of lead poisoning cannot be denied, but this fact, indicative of an excessive formation of red cells, is also an expression of the anaemic state, the gravity of which must be carefully estimated in connection with the number of normoblasts present in the blood. It is therefore advisable in all these cases to test the urine of the patient for the presence of lead.
(4) Moroccan subjects, who are less capable than the French workmen of understanding and adopting the rules of prophylaxis, show signs of lead poisoning in a proportion distinctly higher than the others. On the other hand a smaller proportion of lead colic is noticed in their case histories.

These enquiries agree in general with those of a previous enquiry which was able, in addition, to establish that:

(5) Women are proportionately less affected, without doubt due to the effect of a variety of causes, such as stricter hygiene and prophylaxis, less harmful work, shorter periods of carrying on the trade.

(6) Old workmen show a higher percentage of ill-effects, without however such a marked difference as one would a priori expect: doubtless this is due to the principle of selection, the careless workmen, or those predisposed to attacks of lead poisoning are found to be rapidly eliminated, and do not come into an enquiry of this sort, which deals exclusively with workmen at work at the time of the enquiry.

No surprise need be entertained at conclusions slightly different from those arrived at by investigators in other countries, for in the same factory a change in the system may cause considerable variation in the proportion of the manifestations of lead poisoning. It has been enough, for instance, in a factory where the preparation of the paste and the smearing were originally carried out in the same place, by separating the two operations to obtain a reduction of about 50 per cent. in the cases of poisoning.

In Great Britain a very detailed investigation made by Price and Bridge in 1924 dealt with 34 accumulator factories which employed at the end of June 1923 about 2,490 workmen.

The number of cases of lead poisoning notified to the Factory Department from 1904 to 1924 in accumulator factories was as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Persons</th>
<th>Per 1,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>1904</td>
<td>33</td>
<td>33.3</td>
</tr>
<tr>
<td>1905</td>
<td>27</td>
<td>29.5</td>
</tr>
<tr>
<td>1906</td>
<td>36</td>
<td>29.2</td>
</tr>
<tr>
<td>1907</td>
<td>21</td>
<td>29.5</td>
</tr>
<tr>
<td>1908</td>
<td>25</td>
<td>25.2</td>
</tr>
<tr>
<td>1909</td>
<td>31</td>
<td>27.7</td>
</tr>
<tr>
<td>1910</td>
<td>31</td>
<td>26.5</td>
</tr>
<tr>
<td>1911</td>
<td>24</td>
<td>19.6</td>
</tr>
</tbody>
</table>

These figures show that lead poisoning in this industry has no tendency to decrease in proportion to the number of persons employed, the rate remaining almost the same as is shown by the following table:

<table>
<thead>
<tr>
<th>Year</th>
<th>Persons</th>
<th>Per 1,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>1916</td>
<td>1,362</td>
<td>33.3</td>
</tr>
<tr>
<td>1917</td>
<td>1,378</td>
<td>30.5</td>
</tr>
<tr>
<td>1918</td>
<td>1,539</td>
<td>30.3</td>
</tr>
<tr>
<td>1919</td>
<td>2,061</td>
<td>23.2</td>
</tr>
<tr>
<td>1920</td>
<td>2,395</td>
<td>19.6</td>
</tr>
<tr>
<td>1921</td>
<td>2,087</td>
<td>16.7</td>
</tr>
<tr>
<td>1922</td>
<td>2,101</td>
<td>15.2</td>
</tr>
<tr>
<td>1923</td>
<td>2,490</td>
<td>17.8</td>
</tr>
</tbody>
</table>

But it must be pointed out that generally the cases of lead poisoning are slight. Here are figures concerning the severity of 614 cases reported from 1909 to 1913 and of 208 cases notified from 1919 to 1923 (first half-year):

<table>
<thead>
<tr>
<th>Severity of symptoms:</th>
<th>1909-1913</th>
<th>1919-1923</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>Per cent.</td>
<td>Number</td>
</tr>
<tr>
<td>Serious</td>
<td>34</td>
<td>15</td>
</tr>
<tr>
<td>Moderate</td>
<td>43</td>
<td>57</td>
</tr>
<tr>
<td>Light</td>
<td>87</td>
<td>134</td>
</tr>
<tr>
<td>Unknown</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Number of attacks:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One attack</td>
<td>147</td>
<td>199</td>
</tr>
<tr>
<td>Two attacks</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Three or chronic</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Unknown</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Diseases observed:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gastritis</td>
<td>145</td>
<td>183</td>
</tr>
<tr>
<td>Anaemia</td>
<td>47</td>
<td>98</td>
</tr>
<tr>
<td>Headache</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td>Parestes</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Encephalopathy</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Tremors</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Rheumatism</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Various</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

The cases notified and the attacks of illness are distributed by occupational classification as follows (per 1,000 employed from 1916 to 1922):
two symptoms appear very of lead poisoning, and 78 paleness of the workmen had a complexion characteristic in the department; while 84 per cent, of all among 42 per cent, of workers in the form-

material were the processes offering most that pasting and manipulation of lead in 1925 into accumulator factories showed in 1920.

among pasters was 160 per 1,000 the air was recorded. In this factory in 1919 presence of 10.1 mg. of lead per 10 mc. of pasting and mixing department the pre-
ed lead dust in the sections of the industry explained by the presence of finely divid-

A Japanese Government enquiry made in 1925 into accumulator factories showed that pasting and manipulation of lead material were the processes offering most exposure to lead poisoning. As a matter of fact signs of absorption were noticed among 44 per cent. of paste workers and among 42 per cent. of workers in the forming department; while 84 per cent. of all workmen had a complexion characteristic of lead poisoning, and 78 paleness of the conjunctiva; 78 per cent. showed basophilic granules and 24 paresis of the extensors of the hand. Whilst the first two symptoms appear very early, the third only appears at the end of from one to three years' service. The investigators much regret the slight effort made to instruct workmen against the danger of lead poisoning.

The high averages of this table are explained by the presence of finely divided lead dust in the sections of the industry most affected. Thus, for example, in the pasting and mixing department the presence of 10.1 mg. of lead per 10 mc. of air was recorded. In this factory in 1919 the estimated rate of lead poisoning among pasters was 160 per 1,000 and 157 in 1920.

A Japanese Government enquiry made in 1925 into accumulator factories showed that pasting and manipulation of lead material were the processes offering most exposure to lead poisoning. As a matter of fact signs of absorption were noticed among 44 per cent. of paste workers and among 42 per cent. of workers in the forming department; while 84 per cent. of all workmen had a complexion characteristic of lead poisoning, and 78 paleness of the conjunctiva; 78 per cent. showed basophilic granules and 24 paresis of the extensors of the hand. Whilst the first two symptoms appear very early, the third only appears at the end of from one to three years' service. The investigators much regret the slight effort made to instruct workmen against the danger of lead poisoning.

Pathology

It is not necessary to describe here, or even to enumerate, the diseased conditions originating from lead poisoning noticed among workmen employed in the accumulator industry; that would imply reviewing again the complete story of the absorption of, and poisoning by, lead (see article "Lead Poisoning"). In the same way reference may be made to the corresponding articles for injuries caused by arsenic, mercury, etc.

Hygiene

With regard to prophylaxis against lead poisoning or other morbid conditions produced by the different causes enumerated above, measures of hygiene and improvements in the conditions of work in accumulator factories include, as in every unhealthy industry, the adoption (1) of means for collective protection, more especially directed against the risk arising from injurious fumes and dusts, and (2) of measures for individual protection, especially directed at reducing as much as possible ill-consequences arising in particular from direct handling of lead and its compounds.

Collective Protection

The handling of old plates should be done in the open air and with precaution as these plates, which are strongly charged with oxides of lead in powdered and easily detachable form, may lead to the liberation of poisonous dust.

The melting of these plates, as well as the reduction of the oxides, should be carried out in closed apparatus. Some very interesting contrivances have been devised for this purpose.

In some factories the reducing furnace is connected to the factory chimney. This arrangement causes inside the apparatus a lowering of the pressure which prevents the escape of dust or poisonous fumes into the workroom. The fumes drawn towards the chimney traverse a series of depositing chambers in which they get rid of the lead which they still contain. The emptying of these dust chambers should only be done after sprinkling with water which transforms the dust into paste which can be removed without danger.

In the absence of localised ventilation it is indispensable that running lead obtained from the reducing furnace into ingot moulds should only be done in a very large and well-ventilated place.

In the foundry special precautions should be taken as regards both preparation of plates and of accessories.

The carrying off of fumes emitted by the melting pots is indispensable. This is actually carried out in most works, or, at least, the melting pots are in every case fitted with exhaust hoods intended for removing directly to the outside fumes emitted by the pots of melted alloy.

In actual practice the efficiency of these exhaust hoods is generally doubtful: if, in the vicinity of some places in the works where casting is carried on, traces of lead fumes are only occasionally noted, in others, in spite of the presence of the exhaust hood, perceptible quantities of lead in the vapour state have been detected.

<table>
<thead>
<tr>
<th>Process</th>
<th>Average number of cases notified</th>
<th>Average number of attacks per 1,000 employed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting</td>
<td>4.4</td>
<td>19</td>
</tr>
<tr>
<td>Pasting and mixing</td>
<td>10.9</td>
<td>64</td>
</tr>
<tr>
<td>Mixing only</td>
<td>0.4</td>
<td>16</td>
</tr>
<tr>
<td>Lead burning</td>
<td>3.3</td>
<td>17</td>
</tr>
<tr>
<td>Trimming, filling, cutting,</td>
<td>6.0</td>
<td>33</td>
</tr>
<tr>
<td>Lightning, brushing, etc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling plates</td>
<td>1.0</td>
<td>5</td>
</tr>
<tr>
<td>Assembling</td>
<td>1.4</td>
<td>6</td>
</tr>
<tr>
<td>Melting of scrap metal and</td>
<td>2.4</td>
<td>43</td>
</tr>
<tr>
<td>Old lead plates</td>
<td>5.7</td>
<td>9</td>
</tr>
<tr>
<td>Various</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The draught of an exhaust hood must therefore be verified experimentally; visual examination is not sufficient.

In the same way if the gases withdrawn are not removed into a chimney with a strong draught and sufficiently high, it is indispensable to insure their neutralisation in an acid bath.

The replacement of hand casting by mechanical casting, by means of a special pump, constitutes a great hygienic advance, for the special apparatus can be more completely enclosed which reduces the possibility of lead fumes. The pump similarly dispenses with the use of ladles and all the evil consequences which spring from their use.

In order to prevent the melted lead from cooling too quickly and at the same time not to have to heat it to a very high temperature, heating the moulds before forming the grid patterns has been tried and it is a process which seems to give excellent results.

The use of mechanical moulding has the advantage not only of affording the workman more certain protection against fumes, but also of protecting him against the possibility of serious burns and of preventing the floor from getting covered with drops of lead which in time become dry and reduced to harmful dust. The last danger could be similarly avoided by insisting that workmen abstain from throwing dross on the floor.

Sawing machines are sometimes supplied with glass or celluloid screens which arrest the dust and prevent splinters from striking the faces of the workmen.

The obvious necessity of providing thorough ventilation of places in which the casting of plates and their accessories is carried out need hardly be insisted on. That is the only practical means for ensuring the removal of talc dust, which has been seen to be present in an appreciable quantity in the atmosphere of these places.

During the preparation of paste, dust of litharge and minium is set free. In spite of all precautions and good general ventilation, dust is difficult to avoid if these operations are carried out by hand.

Various firms are now studying means for performing the processes of weighing, mixing and kneading exclusively in closed receptacles and by mechanical means. The adoption of such processes would insure healthy conditions, which are much to be desired in this work. In the meantime it is indispensable for the work to be done only on a surface that can be washed and in a workroom the floor of which is kept constantly moist.

During pasting there is little to fear from dust beyond the special cases dealt with above, and which some factory owners have remedied by utilising perforated or open work tables, thus avoiding deposits of dust. Rooms where the pasting is done should be thoroughly ventilated; their floors should be made of washable material and kept constantly wet.

An old method, almost entirely abandoned, consisted in filling the cells of the plates by means of products previously reduced to powder and strongly compressed. This method of working gave rise to considerable quantities of dust and required the adoption of special measures for providing healthy conditions.

It is not necessary to refer again to these other operations, more or less productive of dust, such as trimming, soldering of connections, brushing of certain plates. The conditions in which the first two are carried out, in the absence of local ventilation which is to be desired, may be improved by carrying on the work on perforated or open worktables, through which the dust passes, as well as fragments of paste which are capable of giving rise to dust.

As regards brushing, its performance under healthy conditions in accumulator factories does not present any special characteristic.

The mixture of gases in the formation room may be dangerous and cause explosions; on account of this and also of the presence of harmful fumes of sulphuric acid, a system of ventilation is rendered necessary, preferably close to the floor where these last fumes have the greatest density.

The protection of the eyes of workmen against ultra-violet rays during autogenous welding justifies the use of special contrivances to combat these rays.

Mercury alloy should so far as possible be avoided, and also the use of impure sulphuric acid containing arsenic, which would lead, on contact with the metal plates, to a liberation of arseniuretted hydrogen.

To sum up, speaking generally, it may be asserted that the injurious nature of the various operations which we have dealt with is all the greater if they are done in combination with each other. In consequence an effort must be made to set apart a workroom or special room for each of them. Thus, in one factory, where the prepara-
tation of the paste and the pasting of the plates were carried on in the same place, it sufficed to separate these two operations in order to effect a reduction of morbidity by half.

Cleaning Workplaces

It is absolutely essential to insist on the necessity for prohibiting dry sweeping. Independently of the legal character of this prohibition it is sufficient, in order to justify it, to recall that dust deposited on the floor and on various objects in an accumulator factory is loaded with lead, as has been seen above.

If it be wondered what the effect of dry sweeping as a harmful factor may be, the answer may be given that samples have shown the presence of 0.0008 grm. of lead per cubic metre of air in the vicinity of a workman carrying out this work. Dry sweeping should be prohibited and replaced by wet sweeping. It is even necessary in some workshops, in particular in the pasting rooms, to arrange the floor in such a way that it can be maintained in a constantly moist state.

Individual Cleanliness

In addition to the collective measures described, precautions taken individually by each workman for his personal protection are also extremely important.

The constant presence in most of the workshops of fumes or lead-laden dust makes it essential to place at the disposal of the personnel warm baths or douche baths. Similarly, it is hardly necessary to show the need of lavatories, for the workmen, whatever their kind of work, have their hands soiled with lead.

In some places workmen are supplied with gloves particularly for smearing and for forming.

In the first case these gloves are intended to preserve the skin from contact with oxides of lead, in the second case they serve to protect the hands against acids.

This means of protection offers great advantages depending, however, on the condition that it is used methodically. Frequently protecting gloves are used intermittently and with the hands already soiled with oxides of lead. During an enquiry it was found that the workman on whose hands the largest quantity of lead was found was a workman employed in pasting, who took off his gloves before washing his hands with the help of a sulpho-tartaric solution.

In some workshops respirators are used, which do not in any way replace the need for local or general ventilation of places in which poisonous dust is set free.

These means of protection in order to be efficient require the direct collaboration of those concerned which is often lacking. Constant supervision of the respirators is also required in order to ensure not only that they are in good condition, but also that they fit perfectly on the faces of those who use them (see article "Breathing Apparatus").

It is certain that in practice most of these conditions, if not nearly all, are frequently ignored, for examination for lead deposited on the nasal mucous membranes of workmen supplied with respirators gave results of the same order as those for workmen not using any protecting apparatus.

The wearing of respirators creates a false sense of security which may have dangerous results. Without denying on that account the use which these articles can render under certain conditions, they should be reserved for the protection of workmen against heavy discharges of dust which are of short duration. In no case should they interfere with the adoption of collective means of protection.

Let it be added in conclusion that to all these measures for improving health conditions by both collective and individual precautions, it would be greatly preferable to introduce, as soon as the problem has been solved, the manufacture of accumulators having the same practical value as lead accumulators, but made without the use of this metal or its derivatives.

Legislation

The employment of women, children and young persons in accumulator factories is subject to rules which legislators lay down concerning work which exposes to risk of lead poisoning (see article "Lead Poisoning").

In Austria the Order of 8 March 1923 on lead compounds also applies to accumulators.

In France the Decree of 1 October 1913 on the particular measures of hygiene for industries where the personnel is exposed to lead poisoning includes also the manufacture of accumulators.

In Germany the Regulations of 6 May 1908 for accumulator factories lay down that the floor shall be impermeable, but not of wood or linoleum for the workshops where lead is handled; that the walls shall be smooth with a washable surface,
or whitewashed and re-done yearly; that the departments of melting, pasting and polishing shall be separate; that exhaust hoods be placed over melting pots and places where soldering is done as well as the mixing places; and that the floor be cleaned daily. The Regulations further provide for monthly medical examination of workmen exposed to risk of lead poisoning, as well as for the discharge of any person showing authenticated symptoms of lead poisoning or absorption.

In Great Britain the Regulations of 19 January 1925 (Statutory Rules and Orders, No. 28, 19 January 1925), which supersede those of 21 November 1903, No. 1,004, prohibit the employment of young persons of less than 18 years of age, in lead operations, except in two operations carried out under special conditions, and of women and young persons of less than 18 years of age, in places in which the manipulation of raw oxide of lead or pasting is carried on.

Manipulation of raw oxide of lead, pasting, drying of pasted plates, formation, with lead burning ("smearing") and melting down of pasted plates must be carried out in separate places, or in such a way that they may be carried on independently from one another and from any other process.

The Regulations provide for each person 500 cubic feet of air and adequate ventilation; the floor must be of impermeable cement or similar material, maintained in sound condition and cleaned wet; damping of the floor of places where lead oxides are handled and where pasting is done is required. Detailed measures are laid down for workplaces and for the various operations that workmen may have to carry out.

Efficient localised exhaust draught must be provided for the operations of melting lead or materials containing lead, for the manipulation of raw oxide of lead, unless done in an enclosed apparatus with ventilation so as to prevent the escape of dust into the workroom, for pasting, trimming, brushing, filing, or any other similar operation which may set free lead dust, and for lead burning.

The products of combustion produced in the heating of any melting pot must not be allowed to escape into a room in which persons work. Receptionists must be provided for the use of workmen in order to collect debris as well as the dose taken from the melting pots.

Persons exposed to the risk of lead poisoning must be medically examined each month, as well as on their return to the factory after a period of suspension from work.

Protective clothing must be provided for every person employed in the manipulation of raw oxide of lead, pasting and formation. This clothing must be impervious to water and, as well as other materials, must be renewed or washed weekly.

The Regulations further provide for canteens, separate changing rooms, lavatories with towels which must be changed daily, and with soap and nail brushes especially for workmen who handle raw oxides of lead.

The employer must allow at least ten minutes before each meal and before the end of the day's work in addition to the regular meal times, in order that workers employed in manipulating raw oxides of lead and in pasting may wash themselves.

Baths with hot and cold water and a liberal provision of soap and towels must be provided for all persons employed in the above-mentioned work.

In Holland measures are also laid down by the Decree of 21 August 1916, Category A.

In India the Act of 1911 lays down measures for mixing and pasting in accumulator factories.

In the United States the accumulator factories committee of the Association of the Edison Lighting Company in 1919 adopted some measures of hygienic protection, which have been approved by the American Safety Academy. The State of Ohio also published in 1914 instructions for workmen to be posted up in workplaces.

As regards the protection of women and children the First International Labour Conference (Washington, 1919) voted a Recommendation having for its object the protection of these persons against lead poisoning on account of the risks with which certain industrial operations threaten women from the maternity point of view, and with the object of allowing children to develop physically. The Recommendation requires that the employment of women and young persons below 18 years should also be forbidden in the operations of mixing or smearing, in the manufacture or repair of electric accumulators, and in the cleaning of workshops where this work is carried on; and that the employment of these persons at work in which lead salts are used is only authorised on condition that the following measures are taken:

Local ventilation of such a kind as to dispel dust and fumes as soon as formed; cleanliness of tools and workshops; notification to the public authority of every case of lead poisoning and awards of compensation to persons poisoned; periodical medical examination of persons employed on the work in question; the provision under satisfactory conditions of changing rooms, lavatories, canteens and of special protective clothing; prohibition of the introduction of food or drink into the workrooms.

On the other hand the Conference recommended that in industries where it is possible to replace soluble salts of lead by non-toxic substances, the use of the so-called soluble salts of lead shall be subjected to the strictest regulations. Any salt of lead is considered soluble which contains more than 5 per cent. of its weight in metallic lead soluble in an aqueous solution of hydrochloric acid of a strength of 0.25 per cent. of acid.
Notification and compensation of sickness arising from lead poisoning are laid down by the special provisions decreed for the notification or compensation of occupational diseases (see articles "Lead Poisoning" and "Occupational Diseases").

Special designing of accumulator factories is only required by French and Russian legislation.

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Acetanilide


Acetanilide, the formula of which is C₆H₅N.H.CO.CH₃, exists in the form of white inodorous crystalline flakes which have a burning taste. It melts at 112-113° C. and reaches boiling point without decomposing at 295° C. Whilst it is only slightly soluble in cold water, it is soluble in boiling water and highly soluble in alcohol and ether. It often contains aniline as an impurity, and then it has a reddish orange colour.

Preparation. — It is obtained by heating for an hour at 180° C. equal parts of aniline and glacial acetic acid. It is isolated by fractional distillation in which only that which comes over at 295° C. is collected.

Use. — In industry it is used in preparing aromatic substances: principally para-nitroaniline and paraphenylenediamine. It is also used as substitute for camphor in the manufacture of celluloid, etc.

Toxicity. — Herczel affirms that acetanilide in strong doses has a poisonous effect similar to that of aniline. Experimentally (Lépine and Porteret), it has been found that a subcutaneous injection of acetanilide has the effect of increasing the quantity of glycogen in the muscles by 20 to 28 per cent. (in guinea pigs). In man and also in animals, even with the strongest doses, only a trace can be found in the urine.

There is no information upon the effects of acetanilide in industry. However, it can be said that it is a virulent poison for the eyes and that it can even cause methaemoglobinemia.

Acetic Acid


Acetic acid, the chemical symbol of which is CH₃.CO.OH, is, when pure, a colourless liquid with a penetrating odour; it solidifies about 16.7° C. in brilliant transparent laminae as glacial acetic acid. It melts at 17° C. and boils at 118° C. Its specific gravity is 1.0553 at 15° C. Its fumes burn with a bluish flame. It combines with water or alcohol in any proportion.

Acetic acid is industrially obtained, either by oxidation under the action of micro-organisms in dilute alcoholic liquors (wine, beer, etc.), the liquid obtained being vinegar, or by dry distillation of wood (see article "Timber Industry"). The acetic acid thus obtained is purified by distillation through bichromate or permanganate of potassium. Synthetic acetic acid is obtained by using as basis acetylene (hydration of acetylene and oxidation of the aldehyde formed).

Acetic acid is used in the textile industry (printing and dyeing of wool and silk; dyeing with alizarine colouring agents: concentration of 35-40 per
ducts, injury from which is compensated.

Acids have been frequently noted by swelling and phlyctena. on contact with the skin lesions characterised by swelling and phlyctena.

Acids are used to dissolve certain acetic ethers and of acetyl-cellulose, and of certain aniline colouring agents; in the preparation of vinegar essence and table vinegar, etc.

Acetic acid is absorbed by animals in the proportion of 65.85 per cent; absorption by human beings seems to be equally easy, especially in small doses. According to Lehmann 47.87 mg. of acetic acid fumes per litre of air inhaled during half an hour do not give rise to serious disorders amongst animals. These fumes exercise, however, an irritant action on the mucous membrane, especially of the eye. Even the concentrated acid only exercises a slight action on the skin, especially if the part affected be washed immediately after.

The action of acetic acid involves no certain risk beyond that of conjunctivitis. The mucous membrane of the throat and nose is, as a rule, but slightly affected. Acetic acid produces on contact with the skin lesions characterised by swelling and phlyctena.

Cases of dermatitis due to acetic acid were reported in Switzerland in 1919; acid burns have been frequently noted amongst hat makers and workers engaged in cleaning bottles and bronze objects. Cases of mercury poisoning have been reported in acetic acid factories where the product is obtained by utilising acetylene in the presence of mercury (as catalyst).

Closed recipients should be used to prevent the escape of fumes.

Acetic acid (anhydrous and concentrated) is included in the list of products, injury from which is compensated as an accident in Switzerland. In Spain girls under twenty-one and boys under sixteen are excluded from work in establishments where acetic acid fumes are given off.

Acetic Aldehyde


Acetic aldehyde, the formula of which is CH₃CHO, is produced by the oxidation of ethyl alcohol by means of potassium bichromate and sulphuric acid. It is a very volatile colourless liquid with a penetrating and suffocating smell. Its specific gravity is 0.795 at 10° C.; its boiling point 21-22° C. It is easily soluble in water, alcohol and ether; it burns with a pale flame; on exposure to the air it becomes oxidised into acetic acid; it easily becomes changed into paraldehyde and metaldehyde.

Preparation. — Aldehyde is prepared by slowly pouring three parts of alcohol (at 50°) and four parts of concentrated sulphuric acid into a solution of three parts of potassium bichromate dissolved in twelve parts of water, and cooling the mixture.

Manganese dioxide can be used instead of potassium bichromate. Industrially, aldehyde is either obtained as a first product in alcohol distilleries, being separated from the alcohol by fractional distillation, or starting from acetylene (see article “Acetic Acid”).

Use. — It is used in the preparation of numerous chemical products, of celluloid, of dyes, of aniline colours (aniline green), of varnishes and of vinegar. It is used also in the manufacture of explosives, silvering mirrors, etc.

Iwanoff found that 0.5 mg. of aldehyde did not produce any injurious effects after five hours; that 2 mg. caused symptoms of marked irritation; these symptoms are very violent with a dose of 3-7 mg., which also produces narcotic effects. A dose of 20 mg. kills an animal in the space of one to two hours. Together with signs of cerebral paralysis are seen oedema and irritation of the lungs. Traces of aldehyde are found in the expired air and a slightly greater quantity in the urine.

Poisoning. — Poisoning produced by inhaling the vapours causes irritation of the mucous membranes of the nose, larynx, bronchi and eyes. The stronger vapours cause a sensation of suffocation and coughing, acceleration of the heart, profuse night sweats, narcotic effects and methaemoglobinuria, etc. Kunkel states that workers suffering from
chronic aldehydism have thickening of the inner lining of the vessels.
Aldehyde is included in the Swiss list of substances liable to produce illness classed with accidents for the purpose of compensation. ***

**Acetone**


Acetone, of which the formula is C₃H₆O (CH₃ CO. CH₃), is a colourless, volatile and inflammable liquid with a smell of ether and a burning taste. Its density is about 0.79 at 18° C. and 0.812 at 0° C. It boils at +56° C., burns with a clear flame and is soluble in water, alcohol, chloroform, and ether.

**Preparation.** — Acetone is obtained by

(a) **Dry distillation of wood**: this method is little used, for the acetone is mixed with methylic alcohol from which it is difficult to separate it. The crude product is treated by bisulphite of soda; it then forms a complex crystal, which is separated by the centrifuge and then decomposed by an alkali (soda). The crude product is purified by distillation.

(b) **Decomposition of acetates**: starting from pyroligneous acid which becomes transformed into dry acetate of lime free of tarry substances. Acetate of lime is given off when dry distillation is carried on at about 300° C.

(c) **Catalytic decomposition of the vapour of acetic acid in the presence of coke containing alumina**.

Acetone can also be obtained from acetylene in the presence of mercury (acting as a catalyst).

**Use.** — Acetone is used at factories for making electric batteries in the manufacture of celluloid boxes (it is in this industry that the greatest risk of poisoning occurs); but it is chiefly used as a solvent in the trades connected with varnishes, paints, resins, metallic colours (bronze powders), india-rubber, chemical products (acetate cellulose, nitrocellulose, celluloid, fatty substances, camphor, etc. usually mixed with amyl acetate, benzol, methylic alcohol, etc.). It is also used in the preparation of chloroform, ketones and certain blue shades, of iodoform and sulphonial; in the preparation of some glues or cements, of zapon lacquer, etc.; in the manufacture of explosives, the preparation of smokeless powder; and in its pure form for burning in the same way as denatured alcohol. As regards the toxic action, the recent experiments of Kagan (1924) show that acetone given to cats by inhalation causes acute poisoning of which the clinical features are the same for all animals and characterised by the following three successive phases: loss of equilibrium, slight and then deep narcosis. The smaller the dose the slower will be the appearance of the symptoms. The personal factor, however, must be taken into account. Small doses given during a long period of time will act in a much more marked manner than strong doses given during a short time.

As regards chronic poisoning (19 experiments upon three cats), Kagan found that the inhalation of 3 to 5 mg. of acetone per litre of air was borne without any injury by the cats and that they became accustomed to acetone. Acetone was found in the urine the day after the experiment, but not at all on the following days even with the strongest concentrations of the poison. Acetone is often rapidly eliminated by the lungs. The toxicity of its vapour (according to Kohn-Abrest) is negligible compared to that of benzene and chloroform: 0.590 grm. of acetone per litre of air does not produce upon the guinea pig even at the end of an hour any symptoms except slight stimulation of the lacrymal glands.

Numerous cases of illness have been noticed among persons occupied in trades using lacquers, varnishes, cements, colours, etc. in which the solvent contains acetone; in the manufacture of india-rubber, of boots, of aeroplane wings, of metal articles (process of painting), etc. In these same trades cases of eczema and conjunctivitis caused by acetone vapour are also noticed fairly frequently.

It should be mentioned that in the manufacture of acetone from acetylene the use of mercury may cause cases of poisoning. In 1914 several workmen were poisoned by mercury in a German acetone factory.

According to Lehmann, acetone causes the same clinical effect as amyl acetate: a hot feeling with vertigo, slight fainting attacks, irritation of the throat, attacks of coughing, etc. Roth considers that the signs of irritation are of primary importance.

Suitable hygienic measures are required to prevent the dispersion of the vapour.
DETECTION OF ACETONE

Transform the acetone into iodoform by the action of a decinormal solution of iodine and of one-fifth normal ammonia. This reaction is not specific.

LEGISLATION

None. (See article "Painting Industry ".)

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### Acetylene

**French: Acétylène (Éthane). — German: Äthylen. — Italian and Spanish: Acetilene.**

**PROPERTIES**

Acetylene, obtained impure by Davy in 1829 and pure by Berthelot in 1859, is a colourless gas with a specially sharp garlic-like smell, unpleasant because of the impurities it may contain, and with a sweetish sugarlike taste, pleasant enough if purified. Its formula is C2H2; its density 0.9056; a litre weighs 1.65 grm.

Acetylene is liquefied easily, in which form it appears as a mobile colourless liquid. It is very refractive (specific gravity 0.451 at 0° C.), which when rapidly evaporated partly solidifies in the form of snow and then melts at —81° C. One kilo of liquid acetylene yields 800 litres of gas at ordinary pressure and 20° C.

During its formation acetylene absorbs 61,000 calories, but being an endothermic compound, only slightly stable, it decomposes readily at a temperature of 750° C., yielding a carbon of the greatest fineness (fine acetylene black). Mixed with air it burns at 480° C.; it explodes violently on contact with a flame or an electric spark, or on detonation with a cap of fulminate of mercury. The risk of explosion occurs more readily and is more dangerous with compressed acetylene (already dangerous at a pressure of 2 atmospheres) and still more so with liquid acetylene. The latter is in a very convenient form, were it not more so with liquid acetylene. The latter is in a very convenient form, were it not more so with liquid acetylene. The latter is in a very convenient form, were it not more so with liquid acetylene. The latter is in a very convenient form, were it not more so with liquid acetylene. The latter is in a very convenient form, were it not more so with liquid acetylene. 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ally the yield should not fall below 250 litres. The reaction requires to be carried out at a temperature below 50° C. as, under the influence of heat, acetylene polymerises with formation of benzene, which gives a smoky flame to acetylene. On the other hand, there is advantage in keeping the temperature of the generators low in order to avoid evaporation of water. This would make the gas moist, which is unsuitable for blowpipe work.

Crude acetylene contains from 10 to 14 per cent. of impurities, including phosphoretted hydrogen (0.8-1 per cent.), carbon bisulphide, hydrogen sulphide (1.5 per cent.), siliciuretted hydrogen (0.8-2 per cent.), arseniuretted hydrogen, as well as other gases such as ammonia, carbon monoxide (1-2 per cent.), hydrogen, nitrogen, oxygen, and hydrocarbons. All the impurities may cause easy or spontaneous combustion of the acetylene, especially the phosphoretted and siliciuretted hydrogen which are auto-inflammable.

As has been already said, these dangers are greatest in the case of acetylene when under a pressure of more than 2 atmospheres. Apart from the unpleasant smell, these impurities account for the poisonousness of acetylene when inhaled for a long time. They are derived from the raw materials (lime, coal, etc.) containing phosphorus, arsenic, sulphur, and silicon, and also from the methods of manufacture (reaction of the carbide on water, influence of local temperatures of heating, etc.). These latter factors notably affect the nature of the impurities (organic sulphur compounds are very complex even in the same carbide) and are present in greater quantity when the gas is produced by means of a dropping apparatus.

Among the impurities, phosphoretted hydrogen plays the most important role. It occurs in impure carbides containing phosphates of calcium (von Jaksch) and causes the spontaneous combustion of acetylene because it favours the formation of explosive metallic acetylenes. According to Jokote and Ichle, American calcium carbides yield an acetylene containing 0.04 per cent. phosphoretted hydrogen. In Swiss acetylene 0.02 per cent. has been found, but Lunge and Cedernkreutz have found up to 0.06 per cent. These quantities would suffice to bring about poisoning, and Dietz has reported a case. According to Hayhurst, acetylene derived from carbides manufactured from lean coal might contain up to 0.01 per cent. of phosphoretted hydrogen as well as hydrogen sulphide, compounds of tellurium, ferrosilicon, etc. The content in phosphoretted hydrogen should not, it is held, exceed 1 grm. per cubic metre.

Purification. — The washed, and in most cases, dried acetylene is next purified by passage through a special mixture or various substances which absorb from 90 to 99 per cent. of the impurities (Zangger).

As absorbent materials, oolitic iron and analogous pulverised minerals are used, milk of lime, hypochlorite, chloride of lime (mixed with sawdust — Lunge and Cedernkreutz), a mixture of chloride of lime and bichromate (Wolff's method), copper chloride (Frank's method); when it is a question of small quantities of gas, with a view to analysis, chromic acid or chrome salts may be used, concentrated sulphuric acid (with arsenious anhydride) or even nitric acid, which, however, cannot be used for large-scale work because the mixture of acetylene with the nitrous fumes would be too dangerous.

Purification by means of chloride of lime is the least costly, gives the best results, and presents the least risk of accident.

In operations in which chlorine gas is evolved very careful absorption should be assured, because a mixture of acetylene and chlorine readily explodes in the light.

Purifying preparations are on the market: "Purethylene" (a mixture of chloride of lime, quick lime and chloride of calcium in granules) a kilo of which can purify 30 cm. of acetylene; "Frankolina" which is a concentrated solution of chloride of copper and other salts. A fossilised earth impregnated with metallic salts is also used.

Zangger reports the heating of the gas until the arseniuretted, phosphoretted and siliciuretted hydrogen are decomposed. In large establishments after purification the acetylene is led into gasometers.

Use — Sources of Poisoning

In the course of purification, effected by oolitic iron and analogous pulverised minerals (see above), the workmen, in drawing the charges, in recharging, in cleaning and repairing, are often the only workmen in the factory in contact with acetylene.

In industry and domestic installations the uses of acetylene are as follows:

(a) Lighting. — Acetylene ignites at a temperature of 480° C. and burns
from an ordinary jet with a reddish, smoky flame, which, however, becomes luminous and very brilliant if the acetylene is made to emerge from a special tap with a narrow slit through a fine opening under a moderate pressure of 7 to 8 cm. of water, or if it is mixed with a little air or inert gas. The best proportions of acetylene and air for maximum luminosity are 3 volumes acetylene and 2 of air. The luminous intensity of acetylene is, at equal volume, fifteen to twenty times that of gas from an ordinary jet, and three and a half to four times that from a jet with an Auer mantle. As a matter of fact special incandescent mantles of rare earths are actually made.

Special mention should be made of the oxy-acetylene lamp with a lime pastille carried to a white heat and used in lanterns, cinematography, etc. First the acetylene flame is lighted and then only is the oxygen added. For signals on railway lines use is also made of dissolved acetylene, which gives the most steady, unchangeable signal, and the one requiring the least attention.

It is also used for lighting purposes in the construction of tunnels, mine shafts, galleries, etc.

(b) For obtaining high temperatures.

The heating power of acetylene is 14,350 grand calories per cubic metre, or 12,300 grand calories per kilo. Burnt in a Bunsen burner a temperature of 2,000° C. can be obtained higher than that from coal gas. This is why the oxy-acetylene blowpipe, giving a temperature of 3,000° C. is used for autogenous soldering in the case of iron and steel. In autogenous cutting of iron or steel the metal to be cut is heated to bright redness in an oxy-acetylene flame; escape of acetylene is then shut off; the oxygen burns the iron, converting it into oxide, which is got rid of by blowing from above. A mixture of acetylene and petrol vapour under the name of "Thermoline" also yields high temperatures.

The use of the blowpipe may produce explosive mixtures which require the adoption of certain technical precautions. The greatest danger comes from the incomplete combustion of the gas. In welding the proportions of acetylene and oxygen ought to be constant, with an optimum amount of the former of 7.3 per cent. With higher amounts combustion is incomplete and hydrogen, water, carbon monoxide, and dioxide are formed. Further, incomplete combustion causes sulphuretted, arseniu-retted, phosphoretted, and silicuretted hydrogen to escape into the atmosphere, as these substances are contained in crude acetylene. When acetylene gas is burnt in the air much nitric oxide is produced, which does not happen with any other flame (Zangger).

An acetylene burner was reported (1919, United States) to have succumbed after having welded for half an hour the interior of a large boiler. Hayhurst believes that this operation exposes the worker to a sixfold risk of poisoning: from acetylene, carbon dioxide, and monoxide (produced by imperfect combustion), sulphuretted hydrogen (from the phosphorus in the coal), and arseniu-retted hydrogen (arising from the hydrogen formed). Acetylene is also used to replace ordinary coal gas for furnace work (glass work, manufacture of incandescent electric lamps, etc.).

(c) As a means of motive force.

New openings have recently been demonstrated for utilising acetylene in internal-combustion engines to replace other hydrocarbons. Acetylene was further used during the war as a carburetted agent.

(d) Its use as an explosive (especially in the liquid form).— Copper, however, gives with acetylene an acetylide of copper which is too explosive to use.

Quite recently, from acetylene as the starting point, a fine resin has been manufactured which, used in combination with pure liquid oxygen, is a very powerful explosive having a speed of propagation of 6,000 to 9,500 metres a second.

(e) Use as a reagent and point of departure in the chemical industry.

In analysis it is used, e.g., to separate copper from its solutions as well as in a series of organic chemical syntheses. Acetylene, by catalytic hydration, in presence of salts of mercury is converted into acetaldehyde, which on oxidation yields acetic acid, and on reduction alcohol (this is more rarely carried out). Acetone can be similarly obtained, crotonic aldehyde with its salts and the acids corresponding to all these bodies.

In the course of these operations the greatest risk is represented by acetaldehyde — a very volatile substance which does not irritate the mucous membranes, but nevertheless impedes the action of the respiratory centre even in low concentrations of 1 in 10,000 up to 1 in 1,000, and thus acts in the same
way as do the fumes of hydrobromic and hydrochloric acids (Zangger).

While it is true that acetaldehyde is converted in the organism by oxidation and fractionation of the acetic acid and carbon dioxide into a series of products which are not poisonous, its action, before oxidation, is of great importance because functional disturbance with a tendency to catarrhal and various digestive disturbances, etc., arise in consequence of the presence of additive compounds. In any case acetaldehyde acts on the nervous system like paraldehyde (product of condensation used as a hypnotic) and on the circulatory system (although in a manner little understood); experiment shows, however, that it may favour the development of the early stages of arteriosclerotic processes.

In addition to acetaldehyde, accessory substances are produced in these operations, notably saturated and unsaturated bodies of which the principal is crotonic acid. Its toxicity is well recognised, because in small doses acting for a period of some months it brings about cardiac irregularity and particularly tachycardia on exertion. These troubles are sometimes excruciatingly painful, especially in young persons. Convalescence takes several months.

The risks to the health of the persons employed in this part of the process can be summed up as follows:

1. Action of volatile aldehydes (acetaldehyde, crotonic aldehyde and allied substances) on the mucous membranes, the digestive tract, the circulatory and nervous systems.

2. Action of the impurities in acetylene.

3. Action of the catalysts (mercury, mercuric oxide, mercurial vapour) in the course of the distillation and recovery of mercury. Further, production of volatile, organic mercurial compounds.

The preparation of acetylene is the starting point for numerous syntheses, and in these the impurities, which give rise to the poisonous character of acetylene, have equally a deleterious effect on the reactions and on the chemical agents present, notably the metallic catalysts. It is thus that in the electrolytic oxidation by means of mercury large quantities of phosphoretted and sulphuretted hydrogen may be produced; and this reaction renders an explosion liable to occur. At the same time a large part of the mercury is precipitated with the phosphorus and the sulphur in the residue in the vat.

When it becomes possible to lower the price of the original product a large number of syntheses will be able to be put on the market, such as those from the manufacture of various chlorinated compounds (ethyl chloride, dichloracetic acid, etc.), the synthesis of indigo, thiophene, and rubber, the preparation of movilith (on condensation from acetylene and monochloracetic acid, chloracetate of vinyl is obtained which, on polymerisation, yields a plastic substance, movilith).

Acetylene is used to make lamp black, of a pure and very fine kind obtained by decomposing acetylene by electrical discharge.

Finally mention should be made of the organic additive compounds — tetrachlorethene, hexachlorothene, tri-chlorethylene — which are to-day the principal substitutes for carbon tetrachloride and carbon bisulphide, while the latter are explosive the former are not. They exert a narcotic action and are powerful solvents of fats and of substances soluble in fats (lacquers, colours, medicinal intermediate products).

Recently (1925) acetylene has been employed to colour lemons yellow (the effect of this gas in artificially giving a lemon a yellow colour is already evident in a proportion of one part in a thousand parts of air; a mixture of acetylene in a proportion of 1 to 5,000 parts of air is used.

Acetylene may also be a by-product in the incomplete combustion of a certain number of carbon compounds, various hydrocarbons (ethane, methane, ether, alcohol, lighting gas into the composition of which it enters to a small extent); in the course of the manufacture of calcium carbide (because of the humidity constantly present in the air, smell of acetylene in carbide factories) mixed with other impurities in the liberation of calcium cyanamide, with calcium carbide in excess as the starting point; in the utilisation of calcium cyanamide, which is often impure and sometimes contains much carbide, in the preparation of chemical products (and more recently for the manufacture of derivatives of urea — Zangger).

Zangger, instancing two cases personally known to him, states that the carbide, rich in phosphorus and nickel, often gives off acetylene containing more phosphoretted hydrogen than the urban by-laws allow in the case of calcium cyanamide.

Mention similarly should be made of the fact that acetylene is produced in
the electrolysis of solutions of alkaline salts and of fumaric and malic acids during the action of silver, copper and zinc on iodoform or of a copper zinc couple on bromoform.

**Danger from Explosion**

The great danger of acetylene lies in the risk of explosion due, on the one hand, to the presence of air or of impurities in the gas and, on the other, to the numerous uses to which it is put. It should be remarked, however, that most accidents are the result of defective apparatus or of faults in handling and use.

Technical details would here be out of place, except to say that it is especially at the moment of purification that the greatest precautions require to be taken because of the presence of phosphoretted hydrogen.

The use of dissolved acetylene is unattended with risk provided certain technical precautions are rigorously observed, especially in the manufacture and recharging of the cylinders. These ought to be of extra soft steel and should be tested at a pressure double that of the charge. They should only contain two-thirds of their capacity of liquid acetylene because the coefficient of expansion is very high. Further, in order to avoid explosion from dissolved acetylene, it is important that pure acetone and pure acetylene should be used. At any rate these are the conclusions come to after recent experimental study in Germany (1922). (See also article "Air (Liquid)").

**Statistics**

Statistics in literature bearing on poisoning by acetylene are very rare. S. Pontopidian (1921) describes one case affecting a young workman using an oxyacetylene blowpipe, but other authorities regard the symptoms and circumstances as indicating rather poisoning by phosphoretted hydrogen. Nicol, quoted by Lehmann, reported two cases of poisoning with symptoms especially of narcosis (see above).

**Toxic Action**

The channel of absorption is by the way of the respiratory tract.

The toxicity may be due to two factors: either the gas itself or the impurities contained in it.

**Toxicity of Acetylene Itself**

It was thought for a long time that this gas acted as a poison like carbon monoxide, but later experience has shown it to be practically non-poisonous, as it is not more toxic than other gaseous carbides like methane, propylene, etc., but it is irrespirable like nitrogen and hydrogen. Really, no simple case of poisoning can be attributed to pure acetylene. Animals do not die in an atmosphere containing 9 per cent. of acetylene, and even in certain cases of 20 per cent. (Kohn-Abrest). Lehmann states that dogs support an atmosphere of 20 per cent. for 60 minutes without showing any signs. Brociner made animals breath gaseous mixtures of acetylene and air or acetylene and oxygen renewed constantly of from 25, 30, and 55 per cent. without poisoning resulting. Malvoz and Crismer had similar results.

Gréhant, however, from quite recent experiments believes that acetylene has a certain toxicity of its own, but only in a very high proportion like that of carbonic acid gas. Asphyxia is very unlikely to result from gaseous mixtures containing proportions of, e.g., 35-40 per cent. Rosemann thinks, however, that 40 per cent. would have a narcotic action.

The most recent researches of Haldane appear to show similarly as one might expect, acetylene being an unsaturated body — that acetylene accumulates in the body, is eliminated with difficulty, and does bring about ill-effects (Zangger). Whatever be the case, blood charged with acetylene shows no particular bad when examined spectroscopically but looks like normal blood (Brociner). If acetylene does combine with haemoglobin, the combination is eminently unstable (Kohn-Abrest).

On the other hand acetylene has anaesthetic properties which have only been medically applied recently.

Acetylene, if used as an anaesthetic, ought to be freed of all such impurities as are likely to make it smell unpleasantly. Mixed with oxygen it is administered in special masks applied over the nose and mouth. The patient loses consciousness in one or two minutes. When administration is stopped consciousness quickly returns: the ill-effects of anaesthesia (nausea, vomiting, and headache) are not completely eliminated, but disappear quickly.

The anaesthetic properties of acetylene appear to be due to an alteration in the absorption of oxygen by the nerve cells. When, however, there is sufficient oxygen present (partial pressure above 16 per cent. of oxygen) acetylene, even if present to the extent of 10 to 20 per cent., produces no narcosis and in many persons causes no malaise — only a
marked degree of reduction in working efficiency (Zangger).

Toxic Action of the Impurities

Numerous authorities (Rambousek, Zangger, Hayhurst, Floret, etc.) admit that the toxicity of industrial acetylene is due principally to the toxic gases which it may contain as impurities (see above).

Recently (1925) Floret insisted afresh on the importance of the impurities contained in the calcium carbide, used in the preparation of acetylene, the organic compounds of sulphur and phosphorus especially ranking first.

Floret emphasises again the fact that the majority of the poisonings attributed to acetylene are in reality due to phosphoretted hydrogen.

Symptoms

The symptomatology relating to acetylene, if it exists, is very obscure. So far as acute poisoning is concerned there is nothing to say. As regards chronic poisoning, Hayhurst describes an acetylene lamp cleaner who suffered for a long time at his work, especially when the lamps were not fit and gave off acetylene gas. The principal symptoms noted were — headache,-nausea, general malaise, feeling of suffocation, and pain over the liver.

According to Floret, effects on respiration may be very serious; often there is loss of consciousness, vomiting, vertigo, headache, and sub-normal temperature in less severe cases. The patient complains of a feeling of cold, which, in the opinion of Lewin and Floret, would appear to be a symptom of poisoning by phosphoretted hydrogen.

As sequelae of acetylene poisoning there have been noted bronchitic symptoms, nervous affections (excitability, trembling of the hands, muscular cramps, exaggerated superficial and deep reflexes, nystagmus, atrhymic action of the heart, tachycardia, etc.).

In acute and sub-acute cases irritation of the mucous membranes and particularly of the conjunctiva have been reported (see articles "Occupational Diseases (Eyes)" and "Welding (Autogenous)").

Diagnosis

This must be based especially on the history and knowledge of the occupation of the patient.

Demonstration

The presence of acetylene in an atmosphere is an indication of incomplete combustion capable of giving rise to other more dangerous substances such as carbon monoxide, phosphoretted hydrogen, etc. The characteristic garlic-like odour of acetylene may sometimes reveal the presence of the gas.

Traces of acetylene in a gaseous mixture are demonstrated by passing a current of the air to be analysed into a solution of ammoniacal cuprous chloride, which gives rise to a reddish brown precipitate of copper acetylide. This reaction is very sensitive and shows 1/200ths of a milligram of acetylene.

Another reagent for acetylene is the sulphate of ammoniacal chromium prot-oxygen which changes it gradually into ethylene (Berthelot).

Bromine absorbs it rather irregularly; ordinary sulphuric acid slowly.

Hygiene

Preventive measures are directed against the risks of explosion and fire: use of relatively small gasometers connected up in lighting installations by iron pipes directly leading to the jets. At every part of the gasometer and pipe connections care must be taken to avoid all use of bronze or copper in order to prevent explosion.

The regulations for unhealthy and dangerous trades lay down measures concerning the industrial manufacture of acetylene, acetylene lighting, storage and manufacture of liquid or compressed acetylene (over or under 1.5 atmospheres), use of apparatus for private individuals, or portable acetylene generators.

Among the conditions to be laid down for factories or storage of liquid and compressed acetylene, it will suffice to state here that they should be away from occupied premises; their construction should be of light incombustible materials; there should be good ventilation, the floor should be of impermeable material; the carbide should be kept in receptacles impermeable to moisture, it should be used as it is wanted; breaking up the pieces of carbide should be done without the creation of dust; lighting by daylight only should be allowed; boiler hearths, if they exist, must be quite away from the workrooms; the solid residues should be collected in a watertight metal reservoir, the milk of lime may be carried into the sewer after dilution with water; the generating apparatus should never be installed in cellars or in underground rooms or parts of inhabited houses; all rubber connections should be rejected; every
precaution should be taken to prevent the freezing of the water in winter, and only hot water should be used for thawing purposes, etc.

**Legislation**

Employment of women and young persons is usually regulated by law excluding them from all processes bringing them into contact with toxic or explosive gases. Most associations for the prevention of industrial accidents, several associations of the chemical industries, as well as State departments of different countries have issued Regulations or Orders regarding safe working in the manufacture or use of acetylene. The recent memorandum issued by the Factory Department of the Home Office, London (Dangers from the Use of Acetylene Gas and in Oxy-Acetylene Welding in Factories, dated November 1922, form 1704), may be cited as an example.

Acetylene is included in the Swiss list of substances for which compensation is accorded as in cases of accidents.

**Prof. H. Zangger**

(Zurich).

**Acids**


The object of this article is merely to assemble general data concerning liquids with an acid reaction, leaving in consequence all detail to be dealt with in the special articles such as "Acetic Acid", "Hydrochloric Acid", "Nitric Acid", etc., "Diseases of the Eye", "Skin Diseases", "Diseases of the Mouth and Teeth", "Gas and Fumes", "Waste Water", etc.

Acids exercise a local action the gravity of which increases with increasing concentration.

In concentrated form these liquids coagulate the protean substance of the tissues and cause lesions which are, however, not so deep-seated or so extensive as those caused by alkalis. Acid burns closely resemble burns caused by fire. In dilute state acids cause dermatitis, chiefly eczematous forms, often noted amongst workers coming in contact with acids. They exercise further a harmful action on nails and teeth and, in the acute form, on the kidneys.

When the skin presents scratches and contusions, which is frequently the case with workers, the acid liquids find a mode of entry through these and then set up very painful and persistent ulcers. The eyes are often attacked by acids, the effect in this case being made more serious than in the case of skin lesions. With dilute acid the lesion is confined to slight causticisation with oedema and hyperemia of the conjunctivae, photophobia, etc.; when in concentrated form, lymphatic circulation of the cornea is caused, with softening, perforation, hypophonia, followed by panophthalmy and blindness.

Poisoning by acids, especially when massive doses are in question, produces a special clinical picture designated by von Jakob "acidity". Apart from the well-known local action there is said to be an indirect action (very, rare in human beings, however) characterised by nervous disorders and due to poverty of the system in alkalis.

Acid fumes are given off in a whole series of industrial operations. It is sufficient to recall in this connection casting of brass, making of storage batteries, manufacture of rubber and of explosives, galvanoplastic processes, the chemical industries, etc.

Acid fumes have been regarded by certain experts as one of the causes responsible for Paget's disease, while certain authorities hold that acid poisoning among certain categories of workers is much more responsible than lead, for instance, in causing this disease— noted by Oettinger and Agasse-Lafont as affecting 15 workers in a total of 31 engaged on work in an acid atmosphere.

**Statistics**

Statistical data will be found in the article "Chemical Trades", since data relating to workers handling acids are often included in total figures for those industries. In Germany, Leymann assembled the following figures for workers in the acid sections of the chemical industries (1881-1904):

<table>
<thead>
<tr>
<th>Acid</th>
<th>Number of Workers (annual average)</th>
<th>Diseases of the Nervous System</th>
<th>Diseases of the Circulatory System</th>
<th>Diseases of the Respiratory System</th>
<th>Diseases of the Digestive System</th>
<th>Diseases of the Urogenital System</th>
<th>Infections</th>
<th>Poisonings</th>
<th>Burns</th>
<th>Other Lesions</th>
<th>Diseases of the Locomotor System</th>
<th>Diseases of the Skin</th>
<th>Diseases of the Eye and Ear</th>
<th>Diseases of the Sexual Organs</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrochloric</td>
<td>863</td>
<td>19</td>
<td>2</td>
<td>127</td>
<td>193</td>
<td>1</td>
<td>86</td>
<td>36</td>
<td>36</td>
<td>78</td>
<td>172</td>
<td>53</td>
<td>8</td>
<td>3</td>
<td>778</td>
</tr>
<tr>
<td>Nitric</td>
<td>1,044</td>
<td>14</td>
<td>2</td>
<td>124</td>
<td>128</td>
<td>2</td>
<td>96</td>
<td>30</td>
<td>30</td>
<td>97</td>
<td>81</td>
<td>40</td>
<td>7</td>
<td>3</td>
<td>720</td>
</tr>
<tr>
<td>Sulphuric</td>
<td>1,389</td>
<td>14</td>
<td>2</td>
<td>210</td>
<td>200</td>
<td>1</td>
<td>98</td>
<td>86</td>
<td>86</td>
<td>124</td>
<td>81</td>
<td>48</td>
<td>7</td>
<td>6</td>
<td>949</td>
</tr>
</tbody>
</table>

Cases of acid burns reached 70 in 1881, 103 in 1890, and 80 in 1900, while eye injuries due to acids numbered 23 from 1881-1890, and 30 from 1890-1900. The last period however bears a higher figure (111) for burns caused by various products. Twenty cases were reported for the period 1900-1904.
Burns accounted in 1907 for a percentage of 11.92 (per 100 accidents) in the chemical industry as against 2.80 for all other workers. They affected various parts of the body in 4.80 per cent.; one single part (exclusive of the eye) in 4.42 per cent.; and eyes only in 2.70 per cent. of the workers in the chemical industry. For all other workers the percentages are as follows: 1.77, 0.57, and 0.53.

Hygienic conditions in the great chemical industry are certainly improved to-day as compared with the past, but the mistake of generalising unduly and imagining that favourable health conditions found in certain countries or met with in certain factories present a true picture of conditions in all factories of this kind must be avoided.

The figures for instance collected by Brückner (1925) for workers engaged in the acid departments of the great chemical works in Germany (Badische Anilin und Soda Fabrik) during 1921 are favourable:

<table>
<thead>
<tr>
<th>Department</th>
<th>Number of accidents</th>
<th>Number of serious accidents</th>
<th>Number of very serious accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitric acid</td>
<td>124</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Mixed acid</td>
<td>1,117</td>
<td>42</td>
<td>10</td>
</tr>
<tr>
<td>Sulphuric acid</td>
<td>3,313</td>
<td>24</td>
<td>9</td>
</tr>
<tr>
<td>Acid (distillatory)</td>
<td>410</td>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td>Denitrification</td>
<td>116</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Galliart towers</td>
<td>170</td>
<td>14</td>
<td>—</td>
</tr>
<tr>
<td>Laboratory</td>
<td>84</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>Nitro-nitration of cotton</td>
<td>1,621</td>
<td>87</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>4,028</td>
<td>206</td>
<td>38</td>
</tr>
</tbody>
</table>

**HYGIENE**

In the case of acid burns, immediate treatment is of first importance. The first thing to be done is to dilute the acid (with water) and to apply compresses of a bicarbonate of soda solution to the part affected. Where the eye is affected, it should be douchèd with water, holding the eyelid well back; such treatment should of course be applied by a competent person (factory nurse). The doctor should be called in immediately. In the English Government factory at Gretna already referred to, the following instructions were distributed to foremen:

Get rid of surface acid by the application of clean water to the part; this may be done by immersing the part in a tub of water, by playing a hose on it, or by leaving the water on it if it is the face or head. Neutralise the acid in the part by applying the alkaline solution and allowing it to act for ten minutes. Gently dry with cotton wool and apply moist picric acid gauze. Cover the surface with a layer of cotton wool and keep in position with a bandage lightly applied. The person who is burned should not be allowed to move the affected part. If the arm is burned a sling should be applied; if the legs are burned, a stretcher should be used. The patient should be seen by the doctor as soon as possible. When the part affected is the eyes or the mouth, it should be washed with alkaline solution and oil applied over the surface.

The manipulation of acid liquids, especially where these are concentrated, should be effected by suitable means so that during transport, pouring, emptying, etc., the worker is not obliged to enter into contact with the liquid, its fumes, or with drops thrown off.

In certain cases it may be advisable to use mask respirators, but it is
always advisable to insist on the wearing of protective glasses.

Precautions should be taken in regard to waste waters with a strong acid reaction (see article "Waste Waters").

Industrial operations involving the use of acids, especially when these are in strong concentration, should be effected in closed apparatus or under ventilation hoods closed by a curtain which can be let down as far as the plane on which the operation is carried out.

Joints of piping should be rendered airtight by applying an acid-proof cement.

Fumes given off, if not recuperated, should be condensed, neutralised, etc., effectively in such a way as to prevent the escape by way of the chimney of all but a minimum quantity of non-condensable acid fumes.

When acids are in basins, vats, tanks or chambers the latter should have an interior lining and should be closed in such a manner as to prevent all escape of fumes. The entry of workers for the purpose of cleaning, repairing, etc., should not be permitted except after adequate measures have been taken to prevent all danger of poisoning or risk to the health.

Inspection services have often drawn up notices to be posted in the workrooms. Similarly associations for accident prevention in the different countries publish a whole series of documents on safety measures appropriate to the use and manipulation of acids. For health precautions in regard to the workrooms, see article "Air of the Workroom."

LEGISLATION

Women are excluded from work involving the use of acid in Argentina (see also articles relating to the various acids). Young persons under 16 years of age are excluded from work involving the use of toxic acids in the United States (Alabama, Arizona, Arkansas, California, Colorado, Connecticut, Florida, Illinois, Kentucky, Maryland, Minnesota, Missouri, Nevada, New Jersey, New York, North Dakota, Ohio, Oklahoma, Pennsylvania, Utah, Vermont, Wisconsin); young persons under 15 years of age are excluded in Greece from the same industries.

Several legislatures have enforced measures of protection for workers handling acids. Thus, for example, English law provides, by section 10 of the Regulations of 11 July 1922 relating to chemical factories, that in all places where strong acids or dangerous corroding liquids are used there shall be provided for recourse in case of extreme urgency: (a) an apparatus for facilitating douching with cold water persons who have received acid splashings; (b) a sufficient number of collyrium bottles filled with distilled water or another appropriate liquid; (c) gloves and protective glasses, or other suitable means of protecting hands and eyes shall be provided for workers required to manipulate acids and corrosive liquids, except in workrooms where manipulation of the said acids or liquids is effected in such a way as to exclude the risk of accident by splashing or by any other means. Gloves shall be collected, examined and cleaned at the end of each working day; they shall be repaired or renewed each time that this is necessary; (d) official notices relating to burning and the risk of asphyxias by gas shall be posted up. For details of the regulations provided by the Alkali, etc., Works Regulations Act of 1901, see article "Gas and Fumes".

Italian legislation excludes women and children from operations enumerated in Table A appended to the Act on the work of women and children (see articles concerning the various acids).

In Norway a Decree dated 29 June 1923 provides for stricter regulation in regard to cleanliness of acid factories and enforces measures in regard thereto (cloakrooms, lavatories, baths, special canteens, exclusion of children, prohibition of the employment of young persons in departments for continuous processes, etc.).

In Russia the Regulations dated 10 April 1922 cover all establishments engaged in the production of mineral salts (exclusive of chloride of lime and chrome salts) as well as the production of chemically pure hydrofluoric and sulphuric acids. These Regulations exclude for instance women and young persons from work in connection with reaction vats (nitric acid factories), from Lorenz vats in decomposition of phosphates by sulphuric acid, from work connected with the recovery of gases liberated during decomposition of phosphates; in the production of hydrochloric, sulphuric and nitric acid, as well as during transport, decanting and bottling and in the production of hydrofluoric acid, etc.: it restricts the length of the working day, deals with hygiene of workrooms, including lighting, heating and ventilation, provision of protective apparatus, medicaments, first-aid boxes, cloakrooms, lavatories, and regulates means of accident prevention, etc.

The Regulations giving effect to the Swiss Federal Law provide by sections 183-189 bis for measures of hygiene in relation to the manipulation and use of acids.

Compensation for occupational disease caused by acids is provided for by English law and by that of the State of Missouri. Japanese legislation provides compensation for ulcers due to mineral acids. In Queensland work involving contact with acid liquids is included in the list of operations to be regarded as entitling the worker to compensation analogous to that provided in the case of accidents.
BIBLIOGRAPHY


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Acridine


CHEMICAL PROPERTIES

Acridine, the chemical formula of which is C₁₃H₁₄N₂, is one of the principal basic constituents of crude anthracene. Pure anthracene crystallises in the form of colourless (yellowish white) needles, melting at 107°-111° C. It is soluble in cold water, more readily soluble in boiling water, alcohol, ether, carbon disulphide, and hydrocarbons. With acids it gives crystallisable salts with a fine greenish blue fluorescence. Heated with nitric acid it gives nitric derivatives; with alcohols and phenols it gives such derivatives as methylacridine, phenylacridine, naphthoacridine, etc.

INDUSTRIAL PREPARATION

Acridine is got from heavy coal tar oils boiling at 300-360° C., by boiling them with sulphuric acid diluted with four times its volume of water. The aqueous solution is then filtered and treated with an alkaline chromate which precipitates the acridine chromate in crystal form. It is thereafter decomposed with ammonia. To obtain absolutely pure acridine, the salt is decomposed several times by heating with ammonia. Synthetic acridine may be prepared in several ways, of which the following is most currently applied. A mixture of diphenylamine, chloroform, chloride of zinc and zinc oxide is heated in an autoclave at 200° C. for seven or eight hours. The resulting mass is dissolved in hydrochloric acid at 22° Be., then plunged into ten times its volume of water and filtered to separate the diphenylamine, and the acridine is thereafter precipitated by means of soda or ammonia. It is then purified by crystallisation in boiling water.

INDUSTRIAL USES

Acridine is used in the preparation of a series of organic colouring matters (animated derivatives) very frequently applied in dyeing textile fibres and leather and especially cotton. Such colouring matters include orange acridine prepared from amido dimethyl-aniline and formic aldehyde, benzoflavine, acridine yellow got from formic aldehyde and meta-toluylenediamine, chrysazline formed in small quantities in the preparation of fuchsine, phosphine or leather yellow, naphthoacrindine, amidoacridine, etc.

SYMPTOMS

Acridine, whether solid or liquid, irritates the skin and the mucous membrane, causing burning and itching. It gives rise to inflammation and twitching of the skin and to violent sneezing. Its salts cause salivation and lachrymation; in grave cases irritation of the skin and mucous membrane is very marked and the rate of respiration and the blood pressure is increased. Derangement of the central and peripheral vascular systems follows. Internally the action of acridine affects primarily the nervous system. It was noted in 1913 that in course of handling coal tar pitch many of the workers developed itching on those parts of the body exposed to light: face, hands, arms, and neck. Such symptoms were found to favour to an extraordinary degree (86 per cent.) fair-haired workers. Lewin ascribes the malady to the absorption of the poisonous substance and the accident of parts exposed to light being affected he attributes to photodynamic action. Amido phenylacridine or phosphine (leather yellow) also exercises an irritant action more marked than that of acridine. (See article "Anthracene".)

LEGISLATION

Injury due to acridine is compensated in Switzerland, which country also excludes young persons under 18 years of age from all processes where risk of exposure to this product is incurred.
Acrolein
(Acrylic Aldehyde or Allylic Aldehyde)
French: Acrélène. — German: Akrolein. —
Italian and Spanish: Akroleña.

CHEMICAL PROPERTIES

Acrolein — formula CH$_2$: CH. CHO or
$\text{C}_3\text{H}_4\text{O}_2$ — is a colourless liquid, soluble
in 40 times its weight of water and in
alcohol, having a disagreeable, acrid,
penetrating and irritating odour (well
known as the odour felt when a tallow
 candle or an oil lamp is extinguished by
blowing). Pure acrolein is an ethereal
substance with a penetrating odour, got by
oxidation of allyl alcohol or dehydration
of glycerine by means of phosphoric
trioxide and potassium bisulphate and a
small amount of neutral potassium sul-
phate.

SOURCES OF POISONING

Apart from such methods of pre-
paration followed in laboratories, the
product is formed in course of several
industrial operations as, for instance,
when fats are burnt and carried to a
high temperature (soap factories, boil-
ing of linseed oil, manufacture of
stearic acid), in the manufacture of
glue from bones, of tallow (refineries),
of lard, in the manufacture of linoleum
and varnishes, in galvanisation and
inning. When the latter operations
are not effected by the galvano tech-
nical process, the metals to be heated are
first corroded in an acid bath, then
placed in melted fat and finally dipped
in the molten metal. Tinning
is generally carried out in a horizontal
tinning machine. The sheet to be
tinned passes through a layer of
molten zinc chloride and subsequently
through a grease pot containing me-
ted palm oil. Acrolein may also be present
during smelting of alloys used for type
in printing, during cleaning of type-
setting machines, in melting down old
greasy type, in the electrical Industry
being used there for insulation pur-
poses, and in the manufacture of cellu-
loid, etc.

SYMPTOMS

Acrolein fumes produce excessive
irritation in the mucous membrane of
the eyes, nose, respiratory passages,
mouth, and throat, causing severe
itching, headache, and nausea. It
gives rise to bronchial catarrh and
more rarely bronchitis. The smallest
dose proved by experiment to set up
symptoms of irritation and gradually
induce slight necrosis is 0.025 mg. per
litre, while 0.01 mg. causes more
marked irritation and recovery there-
from takes several days; 0.2 mg. causes
more deep-seated lesions, and death
was found to occur among animals
about 18 hours after a 24 hours' ex-
posure to 1.6 mg. Post-mortem
examination revealed deterioration of
the lungs and cauterisation of the
mucous of the respiratory organs.
Symptoms similar to the above
have been met with in industry
amongst galvanisers, tinmen, varnish
makers, etc., including workers in all
the processes enumerated above.
Effects experienced include coryza,
dryness of the throat, chest oppres-
sion, loss of appetite due to acrolein fumes
escaping from the pots. From 1912 to
1923 the Factory Inspection Department
in Holland reported 8 cases of poison-
ing.

HYGIENE

Hygiene consists in the provision of
effective localised exhaust ventilation to
draw off fumes at the source of their production. (See articles "Fatty
Substances" and "Soap Industry ".)

LEGISLATION

Compulsory notification of lesions set up
by acrolein is demanded in the Nether-
lands.

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Actinomycosis — Streptotrichosis

French: Actinomyose. — German: Aktino-
mykose. — Italian: Actinomicosi. —
Spanish: Actinomycosis.

These 'two parasitic' affections are
grouped together in one article as their
causes have much in common. Accord-
ing to some authorities, notably Lieske,
they are the same species, endowed
with a power of variability sufficient
to explain the differences ordinarily
noted between actinomycoses and strep-
tothrix. There is no doubt, however,
that on this point, as on the epidemi-
ology generally of the maladies, much
still requires elucidation. One must
confine oneself therefore to matters of
a practical nature in the absence of
assured facts.

AETIOLOGY

The actinomycoses and streptothrix are
imperfect fungi (hypomycetes), compris-
ing forms characterised by slender fla-
ments (0.5 to 1.2 microm.), immobiles, not cellular, ramifying but not by dichotomy, and multiplying by sporulation. The spores of actinomyces are characterised by the tendency to metastases and generalisation of the process. It is characterised by suppurative lesions (abscesses, broncho-pneumonia, pleurisy, pericarditis, pyelonephritis, typhus, etc.), or by neoplasms tending readily to caseate (a pseudo-tubercular process). The spit or pus appears homogeneous and contains the specific germ — generally aerobic — which can be easily cultivated and is pathogenic for laboratory animals (guinea-pigs, rabbits on intraperitoneal inoculation). Ordinary the site of the affection is in the lungs: but it has been reported in the brain, following on meningitis of otic origin. Streptothrix is the cause of certain peculiar mycetomas localised in the feet (madura foot), with formation of nodules in the skin, swelling and infiltration of the soft tissues, followed by atrophy of the muscles and enormous hyperplasia of the conjunctival tissue and formation of markedly pigmented granulation tissue. It is often localised in the lacrymal sac and on the conjunctiva.

**Actinomycosis**

This lesion is characterised by the formation of nodules made up of agglomerations of elementary actinomycotic granulations, surrounded by granulation tissue (hyperplasia). These nodules undergo fatty degeneration and go on to form characteristic abscesses, the pus being yellowish in colour, thin and containing bramble-like yellow grains. These are made up of a central mass of tangled filaments, clubbed at the extremities, which form a peripheral zone to the grain. Union of all these cavities constitutes larger and larger pockets in size (abscesses) and as the process spreads by direct extension from place to place fistulous openings are created which produce the formation of new foci and of metastatic abscesses in different parts of the body. The most frequent seat of election is in the soft tissues near the lower jaw and neck (the masticatory organs, generally of a hard, woody tumour); in the centre of the tongue with hard and diffuse swelling; in the lungs where they are situated in the lower lobes and may be associated with pleural thickening and necrosis of the ribs and vertebrae — by extension of the process along the psoas muscle in the pelvis and even into the muscles and enormous hyperplasia of the conjunctival tissue and formation of markedly pigmented granulation tissue. It is often localised in the lacrymal sac and on the conjunctiva.

**Sources of Infection**

The diffusion of actinomyces and streptothrix in nature is very wide. These parasites may be met with in all kinds of vegetation in the earth, water, air, in dust, in certain foodstuffs (butter, cheese, etc.), and as hosts, apparently inoffensive in the intestine, the mouth, on the tonsils (probably following on ingestion of contaminated foodstuffs) of man or animals. Natural infection of man is rather rare if regard is had to the wide distribution of these moulds. It must be admitted that it does not occur except under certain favourable conditions, such as lesions of the skin or mucous membranes, produced, for example, by the ears of grasses, especially corn, seeds or straw or vegetable debris ordinarily contaminated by moulds. Klinger is of opinion that the pathogenic actinomyces are all anaerobic and incapable of development at temperatures below +30° C.; they are, therefore, of necessity parasites on man and domestic animals, acting perhaps as habitual hosts in the mouth, for example, but only in certain circumstances (presence of bacteria, inflammatory processes, etc.) can they develop pathogenic properties. The fact is that dental caries, with its rich microbial flora, seems to constitute a condition sufficiently favourable for the development of these infections. In view of the prevailing uncertainty on these points it is not possible, at present at any rate, to determine
exactly the occupational risk from these infections. The idea that actinomyces from transpiration to man from cattle, which are frequently victims to the disease, has not yet received any decisive proof in its favour, nor again that it is transmitted from man to man, or that it is the direct action of vegetable debris, ears of corn, etc., chewed or inhaled or acting as a cause of traumatism.

Statistics

According to Delépine 75 per cent. of the cases of actinomyces are occupational in origin. Unfortunately, the published accounts too often do not specify the occupation of the persons attacked: when it has been specified a very large proportion of the cases (about 50 per cent.) have been found to affect agricultural labourers. The malady is common, and Poncet is even of the opinion that "actinomyces is only sought in districts where it is not looked for". The period of year during which infection is most frequent is from July to October, i.e. the harvest times. Of 27 cases treated in 1901 by Rieger at the Surgical Clinic of Jena, 18 occurred among agricultural labourers.

According to Bergenheim the number of cases of actinomyces affecting human beings, treated in the hospitals of the different provinces of Sweden is inversely proportionate to the number of cases reported as affecting cattle.

All workpeople handling straw or grain are particularly subject to risk of contracting the disease: agricultural labourers, packers, those tending cattle or cutting and pressing straw (1 case); those manufacturing articles of straw, straw for bottles, mats; those employed in "basket making", using tresses of straw; those making straw hats, or rush mats (1 case), remaking the bottoms of chairs, etc.

Ulmann in Austria has described a certain number of cases amongst shoemakers and explains their frequency by the multiple punctures made in the tongue and lips by these workers holding the awl in their mouths.

Contagion from vegetable dusts is especially to be feared during the threshing of the grain (actinomyces of the hands: Bertha, of Vienna) and is likely to affect people engaged in commercial handling, storing and especially cleansing of grain (grain distilleries, flour mills, grain crushing, breweries and malting houses, starch factories). In malting houses the danger is especially great when the barley is undergoing dust removal, because owing to the special structure of the grains, in the course of this operation, much fine debris is produced. When African barley is handled the amount of dust produced is well-nigh unbelievable (France).

The most frequent channels of entry are the mucous membrane of the mouth, of the tongue, of the pharynx, the tonsils and even the nose — more rarely of the digestive and respiratory tracts (inhalation of the dust of corn and hay). Sometimes infection takes place through the skin.

Diagnosis

The diagnosis of actinomyces is based on the clinical characteristics of the malady, the peculiar aspect of the lesions, the extreme hardness of the tissues affected, and above all on microscopical examination of the grains in the sanguinolent serum, and better still in value of flowing from the actinomycotic nodules. These grains ordinarily have a diameter varying from between 0.01 and 1 mm.; they are visible when the pus is spread out on a slide placed on a black surface. Microscopical examination is aided by the action of hydrochloric or acetic acid, which dissolves the mass of albumen and the pus globules enclosing the grains, or, again, by the action of hydrochloric or acetic acid, which dissolves the calcareous salts present. Generally speaking, the grains are not very hard and simple pressure of the coverslips crushes them, exposing a granular mass surmounted by a crown of club-shaped filaments or a tangled mass of filament. These peculiarities are well brought out by staining with Gram or Kühne-Weigert.

Direct examination of streptotrichosis without previous fixing and after staining (Gram and basic aniline colours) generally suffices. If the parasite is not readily visible, one can try and dissolve a little pus in a physiological solution, which enables small membranes, generally very rich in parasites and serving very well for cultures, to be obtained (Ciani). These can be prepared by the usual means at ordinary temperature and in the thermostat both aerobically and anaerobically. There are no data as to the practical value of immunisation reaction on diagnosis.

Prophylaxis

In the matter of prophylaxis, in view of the uncertainty of pathogenesis, it suffices to call attention to the danger presented by dental caries, by traumaticisms set up by vegetable products, and generally by wounds soiled by straw, hay and other vegetable débris, espe-
cially at harvest time and from threshing, and to bear in mind also the possibility, although only hypothetical, of the transmission of the disease from animal to man.

Vegetable dust being the usual and most dangerous vehicle, measures of prevention should be directed to its capture at the point of origin and removal outside the workrooms. Difficulty is greater in the matter of threshing and cleaning the grain in agricultural undertakings. The development, however, of mechanical appliances in agriculture promises better protection in the future for the agricultural labourer in these operations. Lastly, personal cleanliness of workpeople employed in dusty atmospheres and maintenance of a proper hygiene of the mouth, which is the most frequent channel of entry for the parasite, should be aimed at. Every excoriation of the skin and every inflammation of the mucous membrane of the mouth should be attended to. The putting of grain, spikes and bits of straw into the mouth should be avoided.

LEGISLATION

Actinomyces is compulsorily notifiable in New Zealand and Dominica. It does not appear in any list of occupational diseases for which compensation should be paid. At the same time, Decaillly, in establishing a parallel between anthrax and occupational actinomyces, regarded as industrial accidents, considers that if the establishment in question comes within the French law of 9 April 1898, reported cases of actinomyces employed in such establishments should be considered as accidents and treated as such under that law.

The Industrial Committee of California has awarded compensation as an accident in one case of actinomyces affecting a workman engaged in putting corn into sacks. Such compensation might also be given under the formula of the legislation in the State of Ohio which recognises compensation for "infection due to dust".

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Prof. D. Ottolenghi (Bologna).

Agricultural Labourers

(Occupational Diseases of)


The hygiene and pathology of agricultural labourers (both general and occupational) varies markedly from one country to another and even from one district of a country to another, for the reason that so many different classes of peasants are to be found. Further, different systems of engaging workers, conditions of living, education and housing, the existence of over population or under population, and consequently of immigration and emigration, all exercise considerable influence on the sanitary conditions of the agricultural labouring class. The peasant on his own little farm or on one he rents, or the small proprietor, the shepherd, the market gardener, or the agricultural labourer engaged by the year or seasonally (e.g. clearing olives, beet, corn, tea, etc.) are all types living under different economical conditions and exposed to various occupational maladies.

If, in general, living conditions are not quite comparable with those of pre-war times, it can be said that they have not been bettered, because to-day very often the agricultural labourer especially prefers quantity to quality in what he eats. Under these conditions the food deficit may not be noticed, but although the stomach may be filled the body is not properly nourished. An improvement in nourishment will not be possible until the time arrives when the indifference and ignorance of the masses has been overcome.

Again, housing is still frequently very defective; dwellings are overcrowded, damp and badly ventilated; too often the stable and the house are one and the same. Under such circumstances the labourer evidently cannot feel encouraged to keep clean a house which affords him no comfort.

Lastly, his hours of work, especially during times of pressure, as in harvest and haymaking times, are themselves a cause of fatigue and overstrain.

As an occupation agriculture certainly presents hygienic advantages in comparison especially with industrial employment, carried on as it is in the open air and under the open sky in sunlight. But there are serious disadvantages such as exposure to rapid changes of temperature and weather, the risk of illness contracted from cold (pneumonia, pleurisy, rheumatism, acute nephritis, sunstroke, heat and cold) to quite a series of accidents (wood cutting, agricultural machinery, tending cattle) and infections, diseases and poisoning; to stings of bees, wasps, snakes, etc. Certain kinds of work such as those in connection with rice fields, flax, hemp,
jute, etc., have particular dangers of their own, e.g. initial fever, similar to hay fever, during the time of ripening of certain plants and vegetables. The skin takes on an icteric tinge, there is headache, fever and general pains, etc. In most cases the attack is benign and incapacity does not last for more than a few days.

A great number of agricultural labourers have to look after cattle and have to spend many hours in stables and cow-sheds which are not always models of cleanliness. In several countries the peasants are known to pass the whole of the winter in the cowhouse to escape the extreme cold.

Except in modern farms and in very advanced centres, the byres are deficient in regard to cubic space, ventilation and cleanliness. The air is vitiated by the products of animal respiration (both from man and beast) and emanation from the litter; it is warm and moist, heavy and nauseating. Children and debilitated persons who go from the cowhouse to the cold, outer air often catch bronchial troubles.

The agricultural labourer looks after the cattle, tends and feeds and doctors them when ill, etc. According to the country, this class works on the land or in the farm buildings. Then, for example, the stockman spends the whole day in the open air, as do also the lads and less skilled labourers who look after the cattle in the fields. In the cowhouse the dairymen are especially occupied with milking operations. They have to get up early in the morning (3 o'clock) and can only sleep from 6 o'clock in the morning until noon when they again resume work. These men are the faithful companions of the animals and interpret their needs: they are their breeders, their nurses and their midwives.

**Sources of Risk**

The special pathology of the agricultural labourer is in strict relation to his various occupations, which can be described as follows: (a) various field operations—meadows, vegetables, beet, potatoes, vineyards, fruit growing, gardening; (b) stock raising and care of cattle; (c) wood working; (d) special work such as rice growing, flax, hemp, etc.

The general view taken is that agriculture has no specific occupational diseases: such maladies as there are being due to long hours and fatigue due to carrying on the head and back heavy loads, especially in the case of children and women, which sometimes cause very serious lesions.

Among the operations in the first group mowing, harvesting, digging and threshing, etc., are certainly arduous, and are accompanied fairly frequently by acute morbid symptoms, the result of fatigue, characterised by fever (39-40° C.) headache, pains in the joints, intense thirst and drowsiness. The attack lasts for one or two days and ceases by crises accompanied by excessive perspiration. Sometimes the attack is mild; some observers believe it to be the result of fatigue and circulatory troubles. Digging is without doubt the most arduous work—especially when carried out in full summer sunlight. Frequent in youthful labourers is an acute inflammation in the tendon sheaths of the flexor muscles of the fingers. The forefinger becomes swollen and the palm of the hand oedematous; flexion of the fingers and especially of the thumb becomes very painful. It is an acute inflammation of the serous tendon sheaths due chiefly to excessive fatigue. The condition is quickly cured by rest. Forced flexion of the trunk produces the result of long continued work also sets up circulatory abdominal disturbance and fairly frequently localised inflammation of certain muscles in the lumbar region recalling the clinical picture of sciatica.

Agricultural labourers engaged in stock-raising and the care of cattle are exposed to the risk of accident and infectious maladies: anthrax, tetanus, glanders, foot and mouth disease, actinomycosis, the bacillus of abortion, etc. Labourers employed in applying copper sulphate in solution in vineyards exhibit pathological anatomical changes in the vertebral column, which, however, are not permanent, as Mori thought, but last during the season (Mazzi). The lateral curvature produced results from carrying the pump on the back and the awkward attitude of the body necessitated by the work.

The question requires more detailed study and is still _sub judice_. These workers may also suffer from poisoning after the use of explosives or from products containing arsenic compounds or carbon bisulphide used to destroy parasites.

Forestry often entails accidents in felling trees which may fall on the woodcutters, or falls of the men themselves when climbing; the agricultural machines and particularly mechanical threshers are a frequent cause of serious accidents (especially evulsion of the arms); the effort to control hail by means of cannon firing exposes the workers to burns and explosions, etc. In field work the labourers' tools—scythes, forks, etc.—may cause very serious damage especially to the lower extremities. Similarly, the processes of vintage wine making, etc., may provoke severe accidents. Further, the
spreading of artificial manures by hand may cause serious inflammation of the mucous membranes of the eyes, and throat, as well as set up pulmonary lesions.

In certain operations also the workers may fall from trees, especially when engaged in gathering fruit or mulberries.

Cases of psychic traumatism among women and children have been reported as a result of attacks from animals, cases which have been complicated with neurasthenia or even insanity, especially in the case of attacks of bulls.

Pellagra, beri-beri, etc., have been known to follow receipt of wages in the form of food where this leads to an insufficient or one-sided nutrition.

Women and children are not infrequently made to carry loads too heavy for them, especially on the head or back, in mountainous districts or at the docks. In this way they carry wood, stones, hay, and vegetables, placing them on their backs or carrying them for long stretches in sacks or baskets. Children of from 8 to 10 years old have been known to carry on their heads weights of 70 kg.: cases have also been reported among women of loss of hair, flattening of the bones of the skull, marked lateral curvature of the spine, displacement of internal organs, cramp of the lateral neck muscles, pulmonary emphysema, "heart weakness," and compensatory curvature of the spinal column, which are not without effect on the female pelvis, rendering childbirth more difficult. This work of weight-carrying for long hours exerts a pressure on the posterior part of the thorax making inspiration more difficult, increasing the predisposition to pulmonary diseases, diminishing oxygenation of the blood and setting up a state of chronic anaemia difficult to cure (Repaci, Bernstein). Among women miscarriages are said to be fairly frequent; at any rate some authorities maintain that they are as frequent as in towns. The medical attendants account for this frequency by the heavy work required of young girls and especially of pregnant women. The sexual organs do not develop physiologically as they should and fail to function normally when desired. The young mother does not rest sufficiently long after childbirth; frequently she is seen walking about the day after. Such conditions easily explain the defective growth of the newly born, their lessened resistance, and reduced chance of survival. Further, they explain also the frequency of maladies of the generative organs (prolapse of the uterus, chronic inflammations, etc.).

Work at too early an age, fatigue, household cases combined with work in the field often require the mother to stop breast feeding; the child is then subjected to irrational feeding, often even insufficient and liable to cause digestive troubles, anaemia, debility and grave nutritional defects which develop slowly but fatally.

Children outside their school hours are occupied in different kinds of work on the field or farm. Sometimes they are even kept from school especially for the more pressing seasonal work.

**STATISTICS**

Statistical data collected by Gherardi (1924) from Italian sources show that for the period 1908-1917 the average mortality rate for agricultural labourers (per 1,000 deaths from all causes) is less than that for all occupations (28.1). In this occupation the various causes of violent death are examined, the following facts are brought out:

<table>
<thead>
<tr>
<th>From falls</th>
<th>Per 1,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stable boys</td>
<td>2.6</td>
</tr>
<tr>
<td>Shepherds</td>
<td>11.6</td>
</tr>
<tr>
<td>Agricultural labourers</td>
<td>11.1</td>
</tr>
<tr>
<td>All occupations</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>From attacks from animals</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Coachmen, stable hands</td>
<td>43.8</td>
</tr>
<tr>
<td>Shepherds</td>
<td>2.3</td>
</tr>
<tr>
<td>Agricultural labourers</td>
<td>1.94</td>
</tr>
<tr>
<td>All occupations</td>
<td>0.66</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>From chills, frostbite, etc.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Shepherds</td>
<td>1.0</td>
</tr>
<tr>
<td>All professions</td>
<td>0.57</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>From lightning</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Shepherds</td>
<td>3.7</td>
</tr>
<tr>
<td>Agricultural labourers</td>
<td>0.8</td>
</tr>
<tr>
<td>All occupations</td>
<td>0.53</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>From sunstroke</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>The mortality generally has been 0.17 per 1,000. Agricultural labourers, shepherds, etc., constitute 38 per cent. of this group.</td>
<td></td>
</tr>
</tbody>
</table>

Insurance of agricultural labourers against accident in Italy is the monopoly of the State Insurance Office: 7½ millions out of about 9 millions are insured. The number of reported accidents was as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Cases</th>
<th>Fatal cases</th>
<th>Per 1,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>1919</td>
<td>36,305</td>
<td>612</td>
<td>—</td>
</tr>
<tr>
<td>1920</td>
<td>41,794</td>
<td>795</td>
<td>—</td>
</tr>
<tr>
<td>1921</td>
<td>55,665</td>
<td>995</td>
<td>7.42</td>
</tr>
<tr>
<td>1922</td>
<td>94,417</td>
<td>1,198</td>
<td>12.59</td>
</tr>
<tr>
<td>1923</td>
<td>75,052</td>
<td>1,070</td>
<td>10.01</td>
</tr>
</tbody>
</table>

The yearly curve of accidents exhibits a peak in March, followed in April by a drop, and another high peak in July (the time of harvest and of the most arduous work in the open), followed by a fall lasting till November.
Occupational mortality for agricultural labourers in the United States shows the following figures:

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Phthisis</th>
<th>Pneumonia</th>
<th>Rickets</th>
<th>Other causes of death</th>
</tr>
</thead>
<tbody>
<tr>
<td>All professions</td>
<td>F. 21.0</td>
<td>7.0</td>
<td>2.2</td>
<td>10.3</td>
</tr>
<tr>
<td>Agricultural la-</td>
<td>M. 14.8</td>
<td>8.0</td>
<td>2.2</td>
<td>11.9</td>
</tr>
<tr>
<td>bourers (Prudential Insurance Co.)</td>
<td>6.0</td>
<td>6.0</td>
<td>2.1</td>
<td>16.3</td>
</tr>
</tbody>
</table>

According to the Prudential Insurance Company, the mean age at death for the period 1911-1913 is 47.9 for all occupations, and 58.5 for agricultural labourers, as compared with only 36.5 for office clerks, etc.

The statistics of the United States for 1910 show an average mortality of 13.8 per 1,000, and of 2.8 for *tuberculosis*. But while there are 18.8 from phthisis out of every 100 deaths from all causes, clerks, accountants, and office employees show a proportion of 22.5, domestic servants 27.4, agricultural labourers only show 17.6 per cent.

As regards cancer, the statistics of the Prudential Insurance Company show for gardeners a value of 8.43 for every 100 deaths, for agricultural labourers of 6.94, and for all classes of the population 5.49 per cent. The statistics of the United States for the period 1911-1913 is 47.9 for all occupations.

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Demanyssus arivm among poultry farmers, tricophyton, favus of domestic animals, Ixodes ricinus, Argas reflexus of pigeons, etc.

Regarding diseases of the eyes or eyelids among agricultural labourers, it will suffice to mention the following: conjunctivitis due to dust raised in the work of grain threshing and packing in sacks, etc.; hay fever set up not only by the pollen of certain flowering plants, but also by the extremely fine hairs found on the surface of leaves and fruits which may be set free in the air (e.g. on the grape leaves when the fruit is ripe: case cited by Villard); lachrymation and erythema of the eyelids occurring among florists. At the same time Zeper, from microscopical examination of the dust of the bulbs of hyacinths, is reported as saying that though they contain none in June and July they do, on the contrary, in August and September contain living acari and their larvae especially Leptus autumnalis. Probably, therefore, these animal agents are the cause of the conjunctival inflammation and erythema, which, according to others, are said to be due to exalate of lime present in remarkable quantity in the bulbs. The dust from crocuses and primroses also sets up analogous affections.

The severe ophthalmia occurring among persons working in flower shops, etc. (Topolanski) and among hop-pickers (Adam) must be attributed to the hairs of flowers and of hops. Persons living in contact with the latter especially may suffer from lesions on the cornea so severe as to lead at times to necrosis of the cornea.

Those who do forest work, and more rarely workers in the fields, show a characteristic eye lesion due to penetration of caterpillar hairs (One-thocampa processionae, Aretis caja, Bombyx rubi). The green and smooth-bodied caterpillars do not set up this affection. A fair number of cases has been described by Elsching and D. Gunn (India).

This malady may even present itself in endemic form among those who collect and destroy caterpillars (Stoermann). At certain times (some days before moulting) the caterpillars appear to lose their hairs more readily, and these set up in persons coming into contact with them catarrhal ophthalmia and dermatitis. The irritating action on the eyes and skin is certainly due to a chemical substance (formic acid?) present in the hair, because mere mechanical action could never set up the clinical picture of nodular ophthal-mia. The loss of tissue which allows the poison to enter the conjunctiva or cornea is provoked by the rigid, cutting part of the hairs themselves. Whatever it be, the researches carried out hitherto seem to exclude action due to microorganisms.

The severest cases, which may last even for years, may be complicated by involvement of the iris. The hairs that have penetrated the sclerotic and anterior chamber reach the choroid (Reis) and set up nodules in it resembling those due to tubercle. Analogous inflammatory conditions often result from the action of the secretion of other insects (aphis, for example), from the stings of wasps and bees, etc. They set up very severe symptoms, especially when the cornea is involved, or inflammatory changes take place in the iris with formation of hypopyon.

Serpiginous ulceration of the cornea is said to be fairly frequent in Germany and to be accountable for two-thirds of the cases of blindness.

Retinitis with opacities in the vitreous have been reported among agricultural labourers after long duration of work in summer without protecting the eyes from the action of the sun's rays.

Antonelli has described a specific disease, vibrio-gangrene of the pupils, which is met with among persons employed in carrying and using manure. There is swelling of the upper eyelid with phlyctenular ulcers which rapidly pass on to a moist gangrene. The chest, face and neck become oedematosus accompanied by high fever, etc. At the end of four, or five days the fever comes down, the necrotic tissues slough off and the patient recovers. Serious deformity of the eyelids (ectropion, etc.) always results. This malady closely resembles malignant pustule due to attenuated anthrax bacilli; it differs, however, in its course and aetiology, as it is due to an anaerobic septic vibrio found in the dung — an ideal culture ground. Soelbrig considers this disease characteristic of southern countries, while Bernstein thinks it can occur also in northern.

A particular conjunctivitis has been described by Gifford in Nebraska. characterised by a painful swelling of the pupils, ulceration of the palpebral conjunctiva and infiltration of the cornea (7 cases in 1922-1923 and 1 in 1924).

Keratomycosis of special type described by Bietti is benign in form; only some dozen cases have been
AGRICULTURAL LABOURERS

described. The first described by Uthhoff and and Axenfeld in 1897 was set up by Aspergillus fumigatus. Bietti has isolated a mould which Saccardi has called Mucor cornealis; in another case Aspergillus flavus and in a third Sporodesmium punctas.

Ophthalmomyiasis localised in the conjunctiva or sometimes in the eyeball (anterior or posterior chamber) is found in Europe more frequently than elsewhere. About 50 cases are known in Europe — 10 in Italy. The causal agent is found in different larvae deposited generally by insects which have flown into the eye, the eggs of which are incubated in the conjunctival sac.

Pterygion and pinguecula are the ocular lesions most frequently found in labourers exposed to dust, particularly those working in the open air and exposed to weather changes (Fuchs, Landsheere, etc.).

Ocular accidents among agricultural labourers are set up primarily by injury, the result of foreign bodies (vegetable and mineral) penetrating the conjunctival mucous membrane readily and coming in contact with the cornea. It will suffice to mention here the injury inflicted by Aspergillus fumigatus, which is carried into the eye by fragments of straw, etc., the small spikes of the husks of chestnut, the small wings of insects, and the husk of grain. All these bodies very often set up keratohypopion, the gravity of which has been recognised, involving, as it often does, loss of an eye.

Labourers in the field are also exposed to more serious accidents to the eyes, the result of blows from the horns of animals (cows, goats, etc.). According to Bertram and Muller's statistics they are more frequent in the left eye, which is explained by the fact that they occur mostly at milking time, the milkman being placed to the left of the animal; other statistics (Eversheim and Hartmann) support the opposite view. As to their frequency it may be recalled that at the ophthalmic clinics of Giessen and Halle they form 8.5 per cent, of all eye accidents. Other statistics state the proportions as 1.8 per cent. Prognosis in these cases depends on whether or not the sclerotic is ruptured. Rupture occurs in about 50 per cent. and is generally situated in the anterior portion, most often above the horizontal midline. Where rupture occurs loss of the eye follows in almost one-half of the cases. Eversheim's statistics show enucleation in 35 per cent. Sometimes the eye lesions are set up by the animal's tail (especially of the ox), flicks from the whip, work tools, etc.

A number of eye injuries are also reported from lightning, which often strikes the labourers when in summer they are surprised by a storm in the open fields and attract the lightning through their wet tools or as a result of the unfortunate habit they have of seeking shelter under the trees.

The development of tuberculosis can be explained by considering the agricultural labouring class as constituting virgin soil unfavourable to resistance against infection. Emigration, forsaking the land for factory life, entry of young girls from the country into towns to take up domestic service, unsanitary conditions, even when the family is in a good economic condition, life in common with children and the aged, work of women in the field even after marriage and during pregnancy, consumption of milk of tuberculous animals, etc., are all factors which play a very important role in the spread of tuberculosis among the agricultural class.

As regards the danger of infection, from bovine tuberculosis, stable boys are admittedly only rarely attacked. Enquiries by Loriga, Maggiora and Gosio, and Terni, etc., bring out the fact that workers of this class, although sensitive to tuberculosis, are not more exposed to risk from bovine tuberculosis than others.

They are, on the other hand, frequently the victims of typhoid fever, of intestinal infections due to the Bacillus coli of oxen and of vaccines. Milkers especially suffer from the last named, but curiously enough infection is frequently conveyed to animals by children who have been recently vaccinated, and then to the cowman or milkman by the animal. Cases of Lichtheimiiasis italic, ondulant fever (especially among goat herds), etc., have also been reported. (See article “Occupational Diseases”.)

Lastly, the frequency among agricultural labourers of diseases of the circulatory organs (heart, blood-vessels, arteriosclerosis, etc.), the digestive organs, and of the peripheral nervous system (neuritis, especially of the fatigued muscles from work such as potato-digging, milking, pressure from tools, carrying sacks of corn, etc.) is noted. In Germany, Coxa vara (Bauerheim) is said to be less frequent now than formerly, although, according to statistics of Bernhardt, 49 were found among agricultural labourers. In old men lordosis of the spine and Coxa vara are frequently seen (Lehmann).
HYGIENE

Agricultural workers require quite a series of legislative measures to improve their lot: housing, water supply, drainage, washing accommodation, and education (even elementary) to demonstrate that women and children should not be subjected to over-arduous and tiring work, and that the workers should not be treated like machines but (like machines in one respect) should be cared for as a good investment.

Quite an education is needed in regard to individual hygiene, proper feeding, antenatal and infant welfare.

Cowsheds should be carefully built so as to secure good ventilation, good natural lighting, adequate water supply for cleaning purposes, etc. There should also be isolation stalls for sick animals. The floor and walls should be easily washed down, windows and indeed all openings should be protected by sackcloth where there is question of infectious diseases like anthrax, glanders, etc. Instruction through leaflets, etc., should be practised; there should be compensation for occupational diseases, accidents, etc.

LEGISLATION

In Holland compulsory notification applies to synovitis of the knee joint, dermatitis and eczema, ulceration of the cornea and conjunctiva in agricultural labourers, as well as to inflammation of joints and cellulitis in gardeners. For both classes of workers, similarly, notification is required of purulent inflammation of the synovial lining of the knee joint and of tetanus.

In Hungary the diseases compensated are enumerated in the Order issued by the Ministry of Agriculture, dated 19 August 1926: anthrax, glanders, infectious diseases, and poisoning by chemical products.

In Brazil the following maladies are treated for compensation purposes like occupational diseases: sunstroke, glanders, tetanus, snake bite, anthracosis, malaria, and Chagas' disease.

New South Wales by special provisions dated 1901 requires, for persons employed in sheep shearing, sleeping accommodation, mess-room and washing accommodation, a sufficient supply of drinking water, sanitary accommodation, etc., maintained in a cleanly condition. Similar provisions apply in other Australian States which (as in the case of Queensland) have extended them to building construction.

The protection of agricultural labourers comes under the regulations of 27 April 1923 applying to factories in Detroit.

In Russia the Compulsory Order of 30 June 1922 deals with protection of agricultural labourers.

From an international point of view, several questions affecting agriculture have been the subject of discussion and resolutions in the course of the Third Session of the International Labour Conference (Geneva, 1921). This Conference made various recommendations, including notably, means of prevention of unemployment; protection of women before and after childbirth (every Member of the International Labour Organisation should take such measures to secure for women employed in agriculture protection similar to that adopted at the First Conference in Washington (1919) for women engaged in industry and commerce; period of absence before and after confinement with compensation during the said period either from public funds or by a system of insurance); as regards night work of women, provision of a rest period suitable to their physique not less than 9 hours on end if possible; age of admission to work (children under 14 years of age ought not to be employed or to work in public or private agricultural concerns or their depots except outside school hours and such work if allowed should not interfere with regular attendance at school; Art. 1). With a vocational object school hours should be arranged so as to allow children to be employed in light agricultural work and particularly at harvest time. The total yearly period of school attendance ought not to be less than 8 months (Art. 2); night work of children and young persons (governed by the requirements of night work for children under 14 years of age, with a rest period suitable to the needs of their physique, etc., not less than 10 consecutive hours); improvement in technical education in agriculture; housing and sleeping accommodation for agricultural labourers (regulations as to conditions of housing and sleeping accommodation bearing in mind special circumstances, climatic and other, affecting work in the field, after consultation with the employers and workers' organisations concerned: this regulation to apply to all places assigned by the employers to the workers, whether single or in groups or with their families, or in the houses of the employer or in buildings placed at their disposal by the employers).

Dwellings intended for families of the working class, etc., should contain rooms capable of being warmed, unless the climatic conditions render that unnecessary.

The rooms should be provided with a bed for each occupant, and so placed as to allow of adequate personal cleanliness. Separate rooms should be assigned to persons of opposite sex. In rooms occupied by families, suitable arrangements should be made for children.

Stables and barns should not be utilised as places for workpeople to sleep in.

Draft Conventions as to rights of association and combination, compensation for accidents and social insurance have also been approved by the Conference.

By 31 March 1926, the Recommendation as to the minimum age for admission had
been ratified by Austria, Bulgaria, Czechoslovakia, Estonia, Ireland, Italy, Japan, Poland, and Sweden. Ratification was also taken into account, especially in Argentina, Chile, Denmark, Spain, and Uruguay. A law applying it has been passed in Bulgaria, Germany, and Hungary.

The Recommendation concerning right of association has been ratified by Austria, Bulgaria, Chile, Czechoslovakia, Estonia, Finland, Germany, Great Britain, India, Ireland, Italy, Latvia, Poland, and Sweden. Ratification was recommended in Argentina, Belgium, Denmark, France, the Netherlands, Spain, and Uruguay.

A Draft Convention concerning compensation for accidents has been ratified by Bulgaria, Chile, Denmark, Estonia, Germany, Great Britain, Ireland, Poland, and Sweden. Ratification was authorised in Hungary, and recommended in Argentina, France, Italy, the Netherlands, Spain, and Uruguay.

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Air: Diminished Pressure

(Rarefied Air)


The chief factors causing troubles reported among persons who spend some time in rarefied air are lowering of atmospheric pressure and of the partial pressure of oxygen, together with alterations in temperature and humidity. Increase in intensity of the solar rays, as well as altered electric conditions of the atmosphere, must also be taken into account, especially when the effect of a stay on high mountains is being studied. In that case the troubles and functional modifications do not depend entirely on the action of rarefied air, but also on the effect of meteorological conditions.

If a stay is made on glaciers or on snowfields, the reflection of the sun and even of mere daylight must be taken into account.

It is known that respiratory exchanges are incompatible with a reduced tension of oxygen when it falls to 3 per cent. of the atmosphere (22.8 mm. of Hg.), for at this tension, at 37° C., almost complete dissociation of oxyhaemoglobin occurs. The result of the formation of this substance in the lungs is a lack of oxygen in the tissues.

Laboratory experiments have shown that if the reduced tension of oxygen descends below two-thirds of the normal strength (20.9 per cent.: 159 mm. of Hg.), the exchange of oxygen between the air and the blood becomes insufficient, and mammals begin to experience symptoms of mountain sickness.

The increase of respiration which occurs at high altitudes is related to diminution in the alveolar tension of carbonic acid, which diminishes according to a rather complicated curve studied by Agatzid. It descends, below a barometric pressure of 500 mm. of Hg., in proportion to it.

In high mountains and especially in the glacier regions, very serious dermatitis sometimes occurs. The mucous membranes of the eyes, nose and upper respiratory passages may also be affected by the action of wind, by ultra-violet radiations from sunlight, by dryness of the air, or by glare from the snow.

The inhabitants as well as animals at high altitudes show a very large number of red blood corpuscles. This phenomenon is also found among persons who reach high altitudes and stay there for a fortnight to six months, according to different writers; they become acclimatised by means of this compensatory mechanism — the increased formation of corpuscles peculiar to high altitudes. Physiologists have not, however, been in agreement as to the origin of this phenomenon, and whereas some of them have considered it arose from an actual increase in number necessary to counterbalance the diminution in the pressure of oxygen in the lungs (the larger number of red blood corpuscles serving to increase the respiratory surface), others have held the opinion that it arose simply from an apparent increase. This would be explained either by an unequal distribution of the red blood corpuscles, or by a thickening of the blood. Some writers, however, have emphasised the complexity of the
phenomenon: Ehrlich and Langlois, among others, have admitted that this phenomenon perhaps includes two phases: a peripheral increase of corpuscles with central scarcity, due to the effect of vasoconstriction and associated with a real increase of corpuscles.

There is now no further doubt that it is a case of real increase in the corpuscles. The haemoglobin also shows an increase with a curve parallel to that of the red blood corpuscles.

The quantitative modifications of red blood corpuscles seem to be less clearly shown in the case of airmen. Research into modifications of white cells and platelets in rarefied air have, up to the present, not given results.

As soon as a man reaches above a certain height (2,000-3,000 metres on the mountains or 4,000 metres in a balloon), he experiences symptoms of varying gravity, although training enables him to overcome this trouble to some extent.

Mountain sickness has been described by climbers of all times. It is chiefly above 3,000 metres, between that altitude and 5,000 metres, that symptoms appear: increasing muscular fatigue making it necessary to breathe often; acute thirst; nausea; vertigo; cephalgia; marked tendency to sleepiness, requiring a strong effort of will to continue climbing. Dyspnœa is noted with increase of pulmonary action, acceleration of pulse and sometimes even palpitations. The pulse rate increases gradually up to a height of 5,000 metres; beyond that the acceleration is still more rapid. If a stay is made at the same level for some time, the pulse tends to become slower.

The arterial pressure does not, however, seem to be noticeably modified. Some writers have noted a slight increase of from 10 to 15 mm. of Hg in cases with good compensation.

The minimum pressure keeps level at 5,000 metres and then shows a fall of 8 to 10 mm. In cases with defective compensation the maximum and minimum pressures may be uncertain and cause faintings. Cyanosis of the lips and face, with a sensation of congestion of the face, have also been noted. These symptoms are more pronounced under certain conditions, as when ascending steep inclines, or in a strong wind. Haemorrhagic complications are rare, as is also syncope. But occasional haemorrhages of the nose and mucous membranes may occur, especially with persons not accustomed to a rarefied atmosphere between 2,500 and 3,000 metres, and these haemorrhages are due to dryness of the mucous membranes.

According to some experts, mountain sickness shows itself under two forms: a toxic form, which is indicated by a sudden prostration, more or less serious, with torpor, an overwhelming feeling of cold, cold sweats, cephalgia, vomiting, oliguria and even anuria, all leading up to coma and death if the subject is not brought down to a lower altitude; and an asphyxia form, characterized by anhæmia, cyanosis, tachycardia, and mental excitement, all of which are generally easily and success-fully treated simply by rest, or the use of oxygen. Some subjects actually show simultaneously signs of poisoning and manifestations of asphyxia.

During decompression there is a rise in the blood urea, which is well demonstrated by keeping an animal for some hours at a reduced atmosphere corresponding to an altitude of from 4,000 to 6,000 metres (R. Wolff).

The prognosis is good, and return to lower regions removes the trouble. This is not the case, however, if the climber persists in continuing his ascent, if he stays too long at high altitudes or if, caught in a snow-storm, he becomes seriously chilled. The death of Dr. Jacottet on Mont Blanc in 1900 from acute oedema of the lungs is an instance in point. He did not wish to descend in spite of the onset of serious symptoms.

In addition to this acute form there exists a subacute and slow form described by Régnier. The journey up is made without incident, but there is no acclimatisation to the stay at a high altitude. Sickness comes on during rest, and results from a series of modifications in nutrition and secretions (Guillemard and Moog, Régnier).

The difficulties which have prevented climbers conquering Mount Everest are too well known to make it necessary to dwell on them here (see Bibliography) 1.

In balloon ascents there is an absence of muscular fatigue; but on the contrary, the system is subjected to a rapid change of atmospheric pressure and to the effects of cold and wind.

1 The English expedition to Mount Everest (1924) found that it was necessary to breathe 7 to 10 times for each step at 8,500 metres. The pulse was 160-180 a minute, regular, rhythmic, and normal in volume: above 8,000 metres dilatation of the heart was found, which required 1 to 3 weeks to disappear. No mental trouble was noted, but at the very great altitudes (8,500 metres) the slightest movements were very fatiguing. The rate of respiration diminished and this diminution was explained by the small proportion of carbonic acid in the alveolar air, due to the great aeration: 56 respirations a minute. This rate at 6,000 metres was less by 3 per cent. than that at 4,550 metres.
In the absence of physical exertion, troubles are rarely noticed among airmen — except in the case of predisposed subjects — below 5,000 metres (Pitard, Von Schroetter). Respiratory troubles do not occur up to this height, even if the ascent is rapid. But pulmonary aeration is increased in consequence of an increase in the depth of respiratory movements. Above 5,000 metres the pulse, rapid at first, becomes small and irregular (at 5,000 metres Crocé-Spinelli had a pulse rate of 155). There occur sensations of cardiac distress, sometimes buzzing in the ears, abdominal distension often accompanied with diarrhoea, nausea and even violent vomiting, which may occur at any height.

Above 6,000 metres the face becomes flushed and the cyanosis pronounced; a state of syncope, mental depression and faintings follow on the least muscular effort (for example, emptying a bag of ballast). Haemorrhages are frequent. Crocé-Spinelli and Sivel, who were killed in the catastrophe of Zenith (15 April 1875), were found with their mouths and noses filled with blood.

At high altitudes (Flemming and Steyrer) a diminution of cardiac and respiratory activity is observed, an almost imperceptible pulse, cramps and tremors of the muscles, sometimes paralysis of the legs and arms, reduction in the central and peripheral sensibility, then troubles of hearing and vision, blindness and deafness, followed by loss of consciousness. Dr. Flemming attributed this to the combined action of cold, flatulent distension of the intestines and passive congestion. All these symptoms call for the administration of oxygen, or better still, a mixture of oxygen and carbonic acid, to prevent a fatal issue.

Although not directly concerned with the subject, there may be noted, with regard to the pathology of aeronauts, other occupational dangers. They are: first and foremost, danger of poisoning from the gases: by carbon monoxide at the time of filling and deflating, or of balloon collisions (several cases are reported by Von Schroetter), by arseniureted hydrogen, 16 cases have been reported by Glaister (Glasgow) in the course of filling or deflating, or during flights. A certain number of cases have been reported in the French army by Maljean, and in the German army by Crone. The ordinary symptoms are malaise, nausea, jaundice, dark and albuminous urine.

In dirigible balloons fresh dangers arise from explosion of spirit, from poisoning by carbon monoxide or hydrocarbons, and from breaking of propellers.

Mountain sickness is analogous to the altitude sickness which affects airmen (see that article), although the two are not absolutely identical.

Mountain sickness described for the first time by Alf. Borelli (1671) after the ascent of Etna has been studied for a long time by physiologists and especially by Mosso.

The pathogenesis of conditions caused by rarefied air seems to indicate several factors.

Whereas P. Bert attributed it to deficiency of oxygen in the blood (anoxaemia), caused in its turn by diminution in the partial pressure of oxygen in the rarefied air, Mosso has advanced the hypothesis of acclimatisation; the reason for this is that mountain sickness is not due to want of oxygen, or at least not exclusively to that fact, but also to diminution in the proportion of carbonic acid in the blood.

The lower limit of partial pressure of oxygen at which it is considered that it is possible to live is ordinarily about 30 mm. of Hg., that is to say, the pressure of half an atmosphere corresponding almost to the maximum altitude at which some races live.

As a matter of fact the acclimatisation of individuals living habitually at high altitude must be borne in mind. Thus in the mines of Cerro del Pasco (4,700 metres) it has been noticed that it is possible to live at an altitude of about 3,000 metres, which is not due to want of oxygen, or at least not exclusively to that fact, but also to diminution in the proportion of carbonic acid in the blood.

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The researches of Mosso, Agazzotti, etc., make it possible to affirm that not only oxygen, but also carbonic acid diminishes in the blood of persons staying at high altitudes; and also that the potential alkalinity, that is to say, resistance to displacement of the reaction, diminishes from 36 to 44 per cent. at 4,500 metres and that this diminution of alkalinity of the blood is in proportion to the diminution of carbonic acid. But the acidosis is not due to lactic acid, which only appears when a height of about 5,000 cent. is reached, nor to amino-acids, nor acetone bodies.

Recently some American physiologists (Y. Henderson, Haggar) have advanced the theory that, in rarefied air there is not an acidosis, but an alkalosis, and that the succession of changes takes place as follows: lowering of the tension of oxygen in the inspired air; stimulation of the respiratory centre by a substance X of unknown nature, which is not a fixed acid; increase of the pulmonary aeration with strong elimination of carbonic acid; diminution of the ratio $\frac{NaHCO_3}{CO_2}$ in the blood; from which alkalosis arises from lowering the concentration of hydrogen ions, and thus alkal disapperes from the blood.

The existence, however, of alkalosis has not up to the present been confirmed by other experts. On the contrary, a loss of alkali by the urine has been proved, which may explain the acidosis (Viale).

There are arguments of clinical and experimental nature to support both theories, and it seems that it may be necessary to adopt an eclectic theory and attribute the conditions partly to auto-intoxication and partly to acapnia.

A third theory has, however, been put forward. According to Raphael Dubois, mountain sickness, distinct from the sickness of aeronauts, resembles seasickness and is due to defective aeration caused by jolting while climbing, which strains the diaphragm; to this is added a low oxygen tension and an increased formation of CO$_2$ due to muscular exertion. The result is an auto-intoxication from uneliminated respiratory waste products, and these troubles are somewhat similar to those caused by confined air.

But other factors may be added to these: flatulent distension of the intestines with pressure on the diaphragm, which interferences with the vital capacity of the lungs (Zuntz), especially in rapid ascents in balloons and aeroplanes; muscular exertion and the products of fatigue (Zuntz, Regnard), which is chiefly true for mountain sickness or for labour in mines, or construction work at high altitudes. For a long time observers (Saussure, Jacquemont, Regnard, Mosso) have noticed this injurious influence, which will explain why alarming symptoms appear much more quickly in mountain sickness than in the sickness of aeronauts. In a hard climb the fatigue is increased because the thorax is overtaxed and also because the products of organic combustion increase; their circulation in the system is also a cause of fatigue. These toxic products clearly explain the insomnia, anorexia and chronic fatigue observed among miners at high altitudes. Among the same workmen the output of work is diminished; for example, in the copper mines of Cerro del Pasco workers can only work in shifts of eight hours for a few months and are then obliged to return to their farms.

Efforts have also been made to explain mountain sickness by vasomotor conditions of the pulmonary circulation.

**Prophylaxis**

Persons suffering from cardiac, pulmonary or renal lesions should abstain from ascending mountains, or making balloon flights.

Healthy individuals should only enter upon great ascents after a methodical training, so as to reduce muscular fatigue as far as possible. Training, by staying at medium altitudes, has the further advantage of encouraging the production of a compensatory increase of blood corpuscles.

The symptomatic treatment of mountain sickness consists in inhaling oxygen. But it is well known that this is not sufficient to keep up the cerebral functions, when there is a deep barometric depression. Whilst acknowledging that oxygen is capable of reviving the depressed functions of the system, when haematoisis becomes insufficient at high altitudes, Mosso, in 1903, tried upon some suffering alpinists, who arrived at the Marguerite Cabin (Monta Rosa), a mixture of oxygen and carbonic acid. Most of them felt the greatest benefit from the mixture (0+13 per cent. of CO$_2$). It is on these lines that work at high altitudes should now be approached.

This efficient remedy is impracticable on the mountains, but can be used in balloon ascents if a face-piece is used to insure automatic breathing of the gaseous mixture, especially in case of loss of consciousness, which would
prevent recourse to this remedy if a face-piece were not used (Croce-Spinelli, Sivel). Rest and warmth are indicated. In case of syncope, as soon as consciousness returns descent must be insisted on. In case of delayed sickness, acclimatisation to lowered pressure may be facilitated by rest in bed, hot and abundant drinks with a diet, of low toxicity, of milk and vegetables.

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**Prof. Herlitzka**

(Turin).

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**Air: Hot and Humid Atmospheres**


**GENERAL**

The temperature and relative humidity of the air in workplaces should be considered as a matter of fundamental importance on account of the influence which they exercise upon the very delicate human heat-regulating apparatus.

As a matter of fact, these physical properties of the air have a value which appears greater as time goes on.

The quantity of aqueous vapour present in the air is in proportion to the quantity of water evaporated and the surrounding temperature; it increases with a rise of temperature. But for each temperature a cubic metre of air can only contain a definitely fixed maximum weight of water. A cubic metre of saturated air contains:

- at — 20° C. 0.8 grm. of water
- — 10° . . . 9
- — 0° . . . 5
- + 10° . . . 33
- + 20° . . . 17.12
- + 30° . . . 30.04

**Absolute humidity** expressed as a percentage is the weight of aqueous vapour contained in a fixed volume of air at a given temperature.

**Relative humidity** is the relation between this weight and that which it would contain if it was saturated at the same temperature.

Example: at 17° C. a cubic metre of air contains 10.1 grm. of water. If it was saturated at the same temperature it would contain 14.43 grm. The relation

$$\frac{10.1}{14.43} = \frac{70}{100}$$

is the hygrometric state of the air tested.

**Deficit of saturation** is the quantity of water expressed in grammes which a cubic meter of air can absorb at the same temperature to cause complete saturation.

**Relative dryness** is the difference between 100 and the value for relative humidity.

In industrial life there is a temperature and humidity which are necessary to efficiency and a temperature and humidity which are inefficient.

**SOURCES OF DANGER**

Furnaces, steam pipes, and chimneys, insufficiently protected against distributing heat and steam, are in certain industries frequent causes of useless rises in temperature and in the degree of humidity of the surrounding atmosphere.

As regards humidity, this depends chiefly on two factors: human exhalations from the lungs and skin, and natural (hygrometric state of the air) or artificial causes.

With respect to this it should be stated that the use of steam or of hot or cold water may be an industrial necessity, as in the textile trades, when a certain hygrometric state of the surrounding air is required.

The industries in which workers are inconvenienced by an excess of moisture are in particular dyeing and bleaching factories, humid cotton mills, wool combing, natural silk spinning, and often factories for colouring materials, the manufacture of potash salts by means of potash from molasses, sugar refineries, and distilleries. Again, certain places should be noted, such as mines, tunnels, submarines, etc. In mines the temperature increases with the depth, 2.5° for about every 100 metres; in submarines it is possible to
reach 26°C or even 28°C with a relative humidity of 100.

It is a common practice for the textile trades to ensure good production by maintaining special conditions of humidity. The fibres work best when the air is warm and humid; that condition prevents the threads from becoming electrified. The parallelism of the fibres and their smoothness are less perfect when the air is not damp and moist.

It is always difficult to fix an optimum temperature and humidity for various trades; the thickness of the fibre in question, the thread to be obtained, and the subsequent processes to be carried out, all requiring to be taken into consideration. The following figures may however be accepted:

<table>
<thead>
<tr>
<th>Trade</th>
<th>Temperature</th>
<th>Humidity</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial wool, Spinning</td>
<td>22-25°C</td>
<td>60-70%</td>
<td></td>
</tr>
<tr>
<td>Average wool</td>
<td>22-25°C</td>
<td>60-70%</td>
<td></td>
</tr>
<tr>
<td>Fine wool</td>
<td>21-25°C</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>Cotton</td>
<td>20-25°C</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>Linen</td>
<td>20-25°C</td>
<td>60-65%</td>
<td></td>
</tr>
<tr>
<td>Jute</td>
<td>20-25°C</td>
<td>65-70%</td>
<td></td>
</tr>
<tr>
<td>Silk</td>
<td>20-25°C</td>
<td>70-75%</td>
<td></td>
</tr>
<tr>
<td>Fine wool Combing</td>
<td>20-25°C</td>
<td>75-80%</td>
<td></td>
</tr>
</tbody>
</table>

In weaving mills more humidity is needed than is spinning mills.

In other trades on the contrary, humidity is useless and does not help any industrial process, e.g. dye works and laundries of the old type.

Steam rises in bleach and dye works, in cleaning factories from two kinds of apparatus: from vats in which objects are treated by a hot process in a suitable liquid at temperatures from 10°C to 150°C (this applies in particular to circulating vats, boat-shaped vessels, tubs, fullers' tanks, etc.), and from apparatus for drying exposed surfaces, used to cause evaporation of moisture from articles to be dried.

In the first case, the surface of the bath emits steam, the amount of which is in proportion to the true surface of the liquid and its temperature and to the movement of the air at the evaporating surface. The surrounding atmospheric pressure must not be forgotten.

It has been calculated, for example, for dyeing vats by A. Turin that, with the liquid at temperature 50°C, evaporation amounts to 2 kg. of water an hour per square metre of evaporating surface, at atmospheric pressure, and a surrounding temperature of 18°C. Under the same external conditions a bath at 95°C gives off 18 kg., and at 100°C it may give off 35 kg. of aqueous vapour per square metre per hour.

The temperature of the combination of air and aqueous vapour causes a rapid ascending current; the cooler layers of air come in contact with the air loaded with aqueous vapour, which will condense according to the principle: "at the same pressure, air absorbs less aqueous vapour in proportion as its temperature is lower."

The air in workshops moves from a cold region to a warm region, that is to say, as a rule it ascends; damp vapour, on the contrary, moves from a warm region to a cold. If the air of the workshop is not agitated, a state of equilibrium can occur, when the vapour remains at a certain level without descending.

In the second case, evaporation is produced by the contact of drying articles with heated cylinders at temperatures well above 100°C. The air above the drying apparatus is at a high temperature and, if the quantity of moisture to be evaporated is not too great, it may remain below its point of saturation. When the apparatus is surmounted by an efficient ventilating hood and the external atmosphere is favourable, a more rapid ascending current is caused; vapour then only forms outside, after contact with cold external air. The fairly high temperature caused by the frame favours the disappearance of vapour from the workroom.

Vapour can always be accidentally formed by a sudden diminution of temperature in the workroom at any point. It is known that if an opening is made in the vertical side of a wall near the floor, a rush of outside air towards the interior of the workroom is observed; if the opening is made high up on the wall near the ceiling, the current is directed in the opposite way. But there is an intermediate height at which the opening made in the vertical wall will neither give entrance to the external air nor act as an exit for the internal air. The plane at this point is called the neutral zone. This plane is at a fixed height for a certain permeability of the walls and always occurs close to the most permeable parts of the walls. If an additional opening is made, the neutral zone tends to approach this opening, which

Now, if a door is opened (naturally at the bottom of the wall under consideration) the equilibrium is broken, the neutral zone tends to fall and cold external air enters the workroom when aqueous vapour condenses and an
opaque mist forms. If, on the contrary, a skylight or a window is opened in the roof, there is logically an exit of hot internal air. But the phenomenon is more complex than one would think, the speed of the wind which opposes this movement outwards playing an important part (A. Turin).

Mist leads to several inconveniences; it causes the workers to remain in a warm and moist atmosphere; and it interferes with the technique of work by obstructing visibility and favouring the causation of accidents from falls and collisions. Then, again, the abundant condensation of steam upon the lining of the roof and walls falls in drops of more or less dirty water and damages merchandise, the walls, and woodwork.

**Physio-Pathology**

As pointed out elsewhere (see article "Air of the Workroom"), excessive atmospheric humidity is harmful to health both at high and at low temperatures. In cool air the body loses heat chiefly by conduction, and moisture in the clothing increases conduction; hence high humidity makes cold air feel colder. In hot air the body loses heat chiefly by evaporation of sweat, and moisture in the atmosphere checks evaporation; hence high humidity makes hot air feel hotter. The combination of high atmospheric temperature and high humidity is peculiarly detrimental both to health and to efficiency.

All the organic functions and biochemical reactions, which are going on without ceasing in the body, are intimately bound up with the heat-regulating function.

Height, age, sex, food, external temperature, and atmospheric pressure exert well-known influences on the respiratory exchanges. Respiratory activity is greater in man than in woman. But, first and foremost, muscular exertion exerts most effect on these exchanges, for it may make the value of these exchanges three or four times greater than when in the resting state.

The system protects itself against surrounding heat by increasing the cutaneous circulation and by increasing evaporation of moisture either from the surface of the skin, or from the lungs. The physical principle upon which this phenomenon is based is the passage to a gaseous state of a certain quantity of water, a change of state which absorbs heat.

It is calculated that to pass from the liquid state (at 37° C.) to the gaseous state 1 kg. of water absorbs 582 calories. Now, an adult man produces an average of 100 calories per hour, that is, 2,400 calories in 24 hours. The evaporation of a litre can then remove all the heat produced in six hours. The quantity of sweat is taken on an average for 24 hours at from 600 to 900 c.c.; in violent exercises it may even reach 400 c.c. per hour.

Through its interference with this evaporative process, atmospheric humidity greatly complicates the influence of atmospheric temperature upon the body. With a relative humidity of 100 per cent. air at 17.2° is as comfortable as air at 20.3 with only 20 per cent. relative humidity and as we proceed to higher temperatures the influence of humidity becomes still more marked.

The Chicago Commission on Ventilation has designed a diagram which shows the comparison existing between temperature and humidity. This diagram gives thus the zone of comfort for the hygrometric degree at a given temperature:

![Relative Humidity Diagram](image_url)

The dotted line shows the optimum zone.

- **Very hot.**
- **Too hot.**
- **Zone of comfort.**
- **Mild.**
- **Too cold.**

Pierce has also drawn up the following table, which shows the comparison...
existing between temperature, humidity and capacity for work.

<table>
<thead>
<tr>
<th>Temperature (in F.)</th>
<th>Relative humidity</th>
<th>Capacity for work</th>
</tr>
</thead>
<tbody>
<tr>
<td>70°</td>
<td>40</td>
<td>Greatest comfort.</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>Comfort when inactive.</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>Depression of fatigue.</td>
</tr>
<tr>
<td>80°</td>
<td>70</td>
<td>No discomfort.</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>Discomfort.</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>Rest necessary.</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>Hard work impossible.</td>
</tr>
<tr>
<td>90°</td>
<td>75</td>
<td>No discomfort.</td>
</tr>
<tr>
<td></td>
<td>85</td>
<td>No work should be done.</td>
</tr>
<tr>
<td></td>
<td>95</td>
<td>Hard work impossible.</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>Production was reduced.</td>
</tr>
<tr>
<td></td>
<td>105</td>
<td>Dangerous to health.</td>
</tr>
</tbody>
</table>

In the article "Air of the Workroom" is reviewed the work of the New York State Commission on Ventilation, which showed a reduction of 15 per cent. in physical work performed at 24°, and of 28 per cent. at 30° as compared with 20° C.

McConnell and Yagloglou, at Pittsburg, have studied productive efficiency under more extreme conditions. Taking a temperature of 32° C. with 30-50 per cent. relative humidity as a base line, they found that production was cut in half by an increase in humidity to the saturation point and a rise in temperature of 1°; or by an increase to 43° with 60 per cent. relative humidity, or to 52° with 50 per cent. relative humidity. Production was reduced to one-quarter at 38° with saturated air, at 48° with 60 per cent. relative humidity, and at 57° with 30 per cent. relative humidity.

Lee has stated that an animal which was submitted for six hours to the influence of hot moist air lost a quarter of its muscular force. Loriga has received the evidence of a director of silk-spinning mills who could foretell the influence of hot moist air on the efficiency of his workers. It was found that the production of silk at 32° C. with 30-50 per cent. humidity was half as much as at 24° C. with 20-30 per cent. humidity, and that production was reduced to one-quarter at 38° with saturated air, at 48° with 60 per cent. humidity, and at 57° with 30 per cent. humidity.

In consequence, the heart uses up a valuable supply of energy; and the nerve centre which regulates and controls the distribution of blood is brought also to a condition of exhaustion.

The experiments made in this field by Wolpert, Haldane, and Langlois are of great interest. By 1907 Haldane had already drawn particular attention to the fact that it is not necessary to measure the loss of water from the body during a fixed period, but that it is better to judge by variations of rectal temperature. If the air is not moving and the subject is at rest and unclad as far as the waist, the temperature of the wet-bulb thermometer, which can bear for several hours, without there being a definite rise of rectal temperature, is from 31° to 32° C. The determining factor will then probably be the temperature as indicated by the wet-bulb thermometer. If this temperature passes beyond the limit just mentioned, the rectal temperature begins to rise regularly, and once the rise has begun it continues until the height of the internal temperature is reached, which occurs, firstly, when the temperature becomes more and more unbearable, with, at last, serious and even fatal results, unless the worker is withdrawn soon enough from the heat and moisture.

If the worker is subjected to muscular exercise, the temperature shown on the wet-bulb thermometer — which is called "the critical temperature" — must be lowered. In this case the rectal temperature begins its rise sooner. And, if the worker wears ordinary clothes, the rise of the internal temperature shows itself sooner — of course an atmosphere at rest is referred to.

There is then some analogy between the wet-bulb thermometer and the bodily system. One might say that the system is "a wet-bulb thermometer which possesses the faculty of automatically accommodating itself to various conditions".

But this faculty of accommodation is not elastic without limit and does not apply to every condition. It happens, under certain conditions, that the rise of the internal temperature is fatal and that continued accommodation to an abnormal condition of things cannot go on without causing trouble. A certain group of factors must still be borne in mind: the constant degree of the individual temperature; the nature of the exertions made; the quantity of heat generated in the interior of the body; the kind, shape, etc., of clothes which cover the body.
the state of saturation of the surrounding air, its movement, etc. It is notorious that in the same place with an identical hygrometric state, two persons are differently affected by a warm and humid atmosphere.

The investigations of Rübner, revised by Benedict, Carpenter, and especially by Langlois, who introduced into the experiments the factor "work", have shown the great importance of muscular exercise and of ventilation on cutaneous or pulmonary evaporation on the one hand, and upon internal temperature and blood pressure on the other. A person placed in an atmosphere saturated with humidity and not ventilated, subjected to work requiring a certain effort, secretes sweat at a rate which, feeble at first, increases after thirty minutes, and reaches a maximum at the end of an hour. This secretion declines from its maximum, but recrudesces a little later to another maximum less accentuated than the first, and so on. It is the fatigue curve of the means of defence of the organism.

According to these tests, it follows that in a saturated and unventilated atmosphere not only does the elimination of sweat take place, following the above-mentioned curve, but that a certain "deficit of saturation" has some influence upon this elimination of sweat, especially in an atmosphere where the movement of air is from two metres a second, and that under the influence of currents of air pulmonary evaporation does not undergo the important changes which are noticed in cutaneous evaporation.

It is necessary then to take into account to a certain extent, the deficit of saturation." But Haldane says that "when the air is constantly hot and moist, and when the factors which contribute to the establishment of a critical temperature are well defined, the temperature is better determined by the wet-bulb thermometer than by any other means.

The factors of import for the fixation of a critical temperature vary according to the industry under consideration — it can even be said according to each individual. It is necessary then to take an average figure and to indicate to what industry this average figure applies.

Thus, for example, a temperature of 25° C. by the wet-bulb thermometer has been considered in France as the critical temperature in mines. In Great Britain the Act of 1911 on cotton weaving prohibits any artificial humidity above 73° F. (29.3° C.) wet bulb.

It is evident that for workers occupied in cotton weaving and wearing ordinary clothes it is desirable that their clothes should not get wet by perspiration. But the situation is different for miners who can work with their clothes off, or stop work when it is too hot. When there is no movement of the air and the wet bulb exceeds 21.1° C., work causes disagreeable sweating if the worker wears clothes similar to those of the weavers, and any temperature above that indicated increases the bad effects pointed out. If the clothes are lighter, the critical point may then be raised some degrees (34° F.).

It should be further added that while it is possible to ventilate mines by means of a sufficiently powerful air current, it is impossible to do so in the same measure in the textile industry, for any rate sufficiently low has a considerable effect upon the critical temperature (see articles "Cotton Industry", "Textile Industry", "Woollen Industry", and "Ventilation").

Though it is generally estimated that a temperature of 23° or 24° C. may be borne, whilst at 20° C. it becomes troublesome, and that at this temperature it is necessary to reduce the humidity to 50 per cent. Nevertheless, some French manufacturers have asserted that a prolonged stay in an atmosphere charged with steam at 20° C. is not at all inconvenient and that a temperature of 23° C. has a troublesome effect (Heim).

Boulin has fixed as a limit a wet-bulb temperature of 24° C. According to this expert, a temperature of 24° C. is almost that admitted by English legislation for cotton weaving, and it represents an average which must not be passed; for at a higher temperature, if the air is stagnant, the workers will be placed under conditions which in the long run will damage their health.

These general conclusions have been fully confirmed by specific practical experience, such as that obtained by Carozzi in the Italian silk mills and by Glibert, of Brussels, in the textile factories of Belgium. Before the British Departmental Committee on Humidity in Cotton Weaving Sheds, experts testified that the workers in mines subjected to a high wet-bulb temperature exhibit a marked degree
of lassitude and exhaustion. According to Professor Cadman, exertion begins to be accompanied with depression from a wet-bulb temperature of about 25° C. At 28° wet bulb "if clothes be removed and maximum body surface exposed, work can be done providing a current of air is available." At 29° "only light work is possible" and at 32° work becomes out of the question (all wet-bulb Centigrade temperatures).

Haldane, in the same enquiry, says that at 31° C. wet bulb a marked rise of body temperature is noted with muscular exercise, and hard and continuous work is impracticable even when the subject is stripped to the waist; while above 31° wet bulb "in fairly still air the body temperature begins to rise, even in the case of persons stripped to the waist and doing no work; and when once started this rise continues until symptoms of heat stroke arise, unless the person leaves the warm air.”

**PATHOLOGY**

**Acute troubles caused by warm and humid air are various.**

They affect the nervous system with violent headache, supra-orbital pain, most varied reflex troubles with syncope, coma, and death in the most serious cases. As regards the circulatory system there occur small pulse, lowered tension, cardiac weakness, reflex congestion of the organs of the body, such as the lungs and intestines.

Troubles connected with thermogenesis manifest themselves sometimes by high and sometimes by low temperature. As regards the excretory, there have been observed oliguria, sometimes dysuria, with urinary hypertoxicity and haemoglobinuria. The blood shows signs of alterations in the red cells.

Finally, more serious phenomena develop, appearing at the same time as, or a little later than, these other troubles, either combined or separate (see later).

But the acute phenomenon of much the greatest importance, and which has been specially studied by medical officers on ships, is **heat stroke**.

In the first degree, the person affected shows weakness and fatigue, a heaviness in the limbs, a kind of asphyxia with early intense dyspnoea, painful congestion of the face and syncope with sudden onset, followed after the acute stage by somnolence and sleep during several hours.

In the second and more severe degree, Jacksonian convulsions (convulsions of stokers) are seen, varying in duration and character, with intention tremors, nystagmus, tetanic crises, clenched hands, hysterical forms with nervous symptoms of the emotional kind, psychoses, heat delirium (mental confusion, hallucinations, illusions, restlessness, sometimes encephalitis) and troubles caused by dilatation of the heart. Heat stroke terminates in sleep and return to complete consciousness and lucid mind, but cases of coma and death are not rare.

In the third degree, death comes with terrible suddenness.

The internal temperature may rise very high, 43°-44° C. A case has been reported where it reached 47.3° C.; and a temperature of 40.5° C. generally causes heat stroke. But it may also occur at a lower temperature when the physical conditions of the surrounding air are very unfavourable.

Heat stroke is accompanied by hyperaemia of the brain and meninges, polynucleosis and hypertension of the sub-arachnoid fluid, various kinds of degeneration of the nerve cells, contraction and sometimes flaccidity of the heart, haemorrhages of the endocardium and pericardium, and pulmonary congestion.

Fiske has reported that heat stroke on ships shows a special clinical picture, characterised by heat syncope which is peculiar to the engineers. The heat-regulating centres are not affected as in sunstroke: fever is moderate and hypopyrexia is quite common. Cold sweats occur, troubles of the circulation and respiration, stupor, muscular phenomena, abdominal pains, muscular contractions due to dehydration of muscular tissues, and diminution in the alkalinity of the blood due to retention of organic acids of malassimilation.

As regards the blood, it has been observed that if the air reaches saturation point, there is hyperglycemia which experts attribute, on the one hand, to troubles of the peripheral circulation, and, on the other hand, to a concentration of the blood mass, as well as to the reaction of the individual to a diminished oxygen supply.

Continued exposure to hot and humid air can, without bringing on the serious troubles described above, cause chronic troubles. Then are observed dyspnoea on effort, nervous irritability, fatigue, lassitude, oppression and torpor. Layet has already described a relaxation of the tissues, a diminution of functional activity with slowing down of the general nutrition, and lymphatism. This organic breakdown is particularly
progressive, and important pathological troubles only show themselves little by little. The difficulties of pulmonary hematomas, digestive troubles with all their consequences, and weakness of nutrition, lead to chronic auto-intoxication with all its reactions, among which may be mentioned anaemia (Layet, Arlidge, Gilbert), which, for example, is the rule in the humid weaving mills. Together with diminution of appetite, digestive troubles, constipation or diarrhoea, especially during high temperatures (the bilious cholera of weavers).

Investigations made by experts of various countries have brought into prominence diseases of the skin favoured by maceration of the corneal layer following on the local action of moisture, some cases of oedema of various parts of the skin — even of those which are not exposed directly to the action of moist air — some rheumatic symptoms, and painful cramps of certain muscles, or muscle groups.

The same investigations have emphasised high sickness and death rates from respiratory diseases and notably from tuberculosis, high infantile death rate, and, among women, frequency of abortions and miscarriages (see articles "Textile Industry", "Cotton Industry", "Silk Industry", etc.).

**CONTROL OF WARM AND HUMID ATMOSPHERES**

Temperature is measured directly by thermometers. Experts estimate that the temperature should not exceed 20-21.50° C. for active workers, 18-20° C. for semi-active workers, and 19° C. for those employed in hard work.

Humidity is measured in various ways:

1. By *hygrometers*: (a) which act by condensation, based on the temperature of the dew point — too delicate for industrial purposes; (b) which act by absorption, not very exact, but able to be used as an indicating apparatus; and (c) which act by compensation. A good hygrometer should be easy to handle and within the reach of all; it should rapidly give the degree of saturation of the air or the temperature of the dew point and give the indication as approximately as possible.

2. By *psychrometers*: a psychrometer is made of an ordinary or dry-bulb thermometer, and another called "the wet bulb" because the bulb is surrounded by muslin dipping into a reservoir of water which keeps it moist and maintains at the surface a constant evaporation. The heat from the evaporation of the water is taken up by the reservoir of the thermometer, so that the wet bulb shows a temperature (t₁) lower than the other (t). The difference t₁ — t is so much the greater as the evaporation is the more rapid, which occurs when the air is dry, that is to say, more removed from saturation point. It is nil when the air is saturated.

The tension (F) of aqueous vapour is calculated in mm. of mercury, according to psychrometric observations by means of the formula:

\[
F = F₁ = h \left( T₁ - T \right)
\]

where:

- \( h \) = the barometric pressure
- \( T₁ \) = the temperature of the wet bulb
- \( F₁ \) = the maximum tension of aqueous vapour corresponding to the temperature \( T₁ \).

The use of the wet bulb naturally requires precautions. Two thermometers differently placed and supported in different ways will give different readings. The proximity of a pillar or a wall, the composition of the materials used to make such a pillar or wall, the nature of the water used for moistening the muslin, the position of the psychrometer in a small or large room where the relative humidity is however the same, the movement or stagnation of the air, are all factors capable of varying the reading.

Some ordinary psychrometers will not generally yield accurate results since in still air the wet bulb becomes surrounded by a layer of moisture which prevents the evaporation which would naturally be caused by the air of the room as a whole. A more satisfactory type consists of an ordinary psychrometer usually mounted on a handle which permits it to be swung back and forth for a minute or so before a reading is taken so as to expose the bulbs to a representative atmosphere. The silk envelope of the wet bulb is freshly moistened just before each reading. Such a device is known as a sling psychrometer.

The results of psychrometric readings are usually expressed in terms of relative humidity. Since \( T₂ \) is the relative humidity, it is the absolute amount of water vapour which determines the drying influence of the atmosphere upon the human body.

In order to do away with the chief cause of error in the use of the psychrometric formula, "psychrometry by aspiration" has been proposed (W. Lambrecht). It indicates in less than a minute the exact temperatures, allowing, by the use of the tables drawn up by Jellinek, the degree of saturation of the air to be obtained within less than a hundredth of a degree.

The instrument is contrived so that by one turn of a crank each second the air is displaced against the bulb of the thermometer at a rate of about 0.50 metres per second.

The same maker has produced a psychrometrograph which enables one to read with the greatest possible exactness the readings of the psychrometer. Lambrecht has made as well "an indicator of the dew point". Into a sort of capsule containing ether, of which one of the faces forms a mirror of polished
metal, is plunged the bulb of a very sensitive control thermometer. By means of an india-rubber bulb, air is blown into the capsule causing in this way rapid evaporation of ether, that is to say, a progressive cooling extending to the thermometer and to the metal mirror and surrounding atmosphere. When the point of saturation of this atmosphere has been reached, the metal mirror a slight cloud standing out distinctly from the edge of the mirror, which remains bright. At this precise moment the temperature is read, which is none other than the temperature of saturation point of the air in the confined atmosphere and in the external atmosphere. If at the same time a thermometer is arranged to record the temperature, upon the air, it is easy to calculate the relative humidity.

Bellon, moreover, formulates this rule, of great importance in the domain of general hygiene, of ventilation: *If, in a closed place, where persons are required to stay, the ventilation is carried on in such a manner that it ensures a maximum of pure air, there should only be found a difference at the temperature of the saturation point of the air in the confined atmosphere, and in the external atmosphere.*

Proved that certain precautions are taken, the readings of a psychrometer have a certain physiological value, although they have only a relative value from the physical view, properly so called.

In practice each apparatus is supplied with tables of psychrometric readings, more or less exact. It is then possible to determine with sufficient accuracy the hygrometric state of a sample of air and its temperature, and to know, upon the basis of the difference between the two thermometers, the number of grammes of water per cubic metre of air.

(3) By the katathermometer: Leonard Hill some years ago suggested a spirit thermometer ranging from 100° F. (37° C.) to 95° F. (35° C.) which can be used as a dry-bulb or a wet-bulb thermometer. In this way an apparatus is provided which records not only the degree of humidity of the surrounding air, but also the movement of the air.

Instead of noting the temperature at which the spirit becomes steady in the two cases, the rate of cooling is registered, that is to say, the time which the spirit takes to descend from 100° to 95° F. With this object the apparatus is warmed by immersion in hot water at well over 100° F., the apparatus being used either with or without a covering of muslin according to whether it is used as a dry-bulb or a wet-bulb thermometer. It is hung in the air to be examined and the time of cooling is noted. The dry kata cools by radiation and convection, whilst the wet kata cools by radiation, convection, and evaporation—the evaporation depending on the hygrometric state of the air and its movement. When simultaneous observations are made with the dry and wet kata, formulas permit the hygrometric state of the air and its rapidity of movement to be calculated. As a matter of fact the total quantity of heat lost in cooling from 100° to 95° F., expressed in microlcalories, divided by the surface of the katathermometer, gives the loss of heat in microlcalories per square centimetres—characteristic for each instrument which constitutes its coefficient and is engraved thereon.

Provided the systematic experiments of P. Weiss (1925) show that each temperature is closely associated with a most favourable rate of air movement, which permits the body at rest to experience in these conditions a loss of heat almost equal to that which it experiences in motionless air at 18° C. An analogous connection exists between the temperature of the air and the kata index, for there exists for each temperature of the air a kata index which corresponds to the most favourable conditions for heat-loss.

Investigations made by Weiss to determine the existence of an analogous connection for humid air have not led to results, for, while the wet kata reacts to variations in humidity, the temperature of the skin does not react within limits that can be accurately measured.

Computations of the various combinations of temperature, humidity and air movement which produce an equivalent sensation of comfort, based on the experiments of the U.S. Bureau of Mines at Pittsburg, Pa., are cited in another place (see article "Air of the Workroom").

**HYGIENE**

Prophylactic measures naturally vary according to whether a warm humid atmosphere is necessary for the process or not.

In this latter case all radiation of heat must be avoided by employing coverings for boilers, non-heat-conducting lagging, furnaces with a double lining with circulation of water, protection by screens, curtains of asbestos canvas, ventilation in front of fires, humidification or ventilation with...
humidification; while all escape of aqueous vapour and steam must be avoided.

Aqueous vapour exists in the latent state in the atmosphere on account of its high temperature.

But when the temperature is lowered, moisture condenses on the walls and roof of the workroom creating a mist which sometimes goes so far as to pervade the whole room. This also happens when steam cools as it escapes from hot water vats into an atmosphere already saturated. The mists are naturally more frequent in winter than in summer.

In order to disperse mist, two methods may be used: first, by rewarming the atmosphere of the workroom to a temperature at which the quantity of aqueous vapour set free cannot saturate the air, or, secondly, by sending into the workroom a volume of warm air which remains under the saturation point.

The first method should not be adopted, for it will bring the surrounding air to an inadmissibly high temperature.

As the temperature of a workroom should be a fixed datum of the problem to be solved (from 20° to 23° C. maximum), the second method should henceforth be put into practice.

Nevertheless, for several reasons, ventilation more than is strictly necessary for desaturating the air should be provided. And air drawn in from the outside must be warmed to a suitable temperature so that it disperses into the room the calories lost by the walls, roof, and floor, and so that it maintains in the workroom a temperature of 20° C.

In order to prevent the re-entry of outside air, causing the accidental formation of mist, it will be necessary to lower the "neutral zone" as far as the level of the floor and below the plane of formation of the mist. To this end it is enough to create in the workshop an increased pressure, so that it can oppose the external pressure which tends to arise naturally.

Condensation can be theoretically avoided by suitably changing the air in order to keep it at a degree of humidity sufficiently distant from its point of saturation, so that when it cools, through contact with cold walls and roof, it does not reach saturation point. This problem is, however, complex, the construction of the building coming under consideration.

Elimination of mist from a workroom can be obtained by sending in a current of warm air of fixed temperature, of calculated amount, and at a suitable height, but this installation should be made as economical as possible. As far as possible the use of live steam should be avoided for heating air, and the greatest possible use should be made of waste heat, that is to say, to recover unused calories. It is a technical problem which a skilled expert should be able to solve easily.

Without passing in review the principal means of heating the air, it will be enough to stress that apparatus should be placed judiciously in the workroom or outside, and combined with artificial ventilation (see article "Ventilation").

When warmth and humidity are necessary, the problem of maintaining a healthy atmosphere is certainly serious and complex, all the more so as factory owners take the opportunity of exceeding the limits which experts have fixed.

To solve the problem of desaturation of the atmosphere, it is necessary to take into account certain secondary difficulties, such for example as: the process carried on in the workshop, determining as exactly as possible the quantity of aqueous vapour produced; the length of time that hot and moist objects remain in the workshop, which is especially important when the manipulations are slow; the temperature of vats; the external surface of vats and its nature; the construction of the building; the kind of roof, whether of reinforced concrete, without insulation by paper or air, or special tiles; the number of doors; the surroundings, which are important from the point of view of warming and also of removing moist air.

In order to prevent sickness, certain conditions of temperature and humidity must, according to Haldane, be maintained. This writer has been able to determine that in still air the rectal temperature of workers begins to rise as soon as the wet bulb marks 31-32° C., the subject being half dressed and not doing any work. If the thermometer keeps at this degree in a humid atmosphere, the rectal temperature continues to rise until trouble ensues.

If the subject is doing only a moderate amount of work in a still atmosphere, the rectal temperature commences to rise when the wet bulb only registers 26° C.

This is why this English expert asks for no rise of the wet bulb above 24° C. for textile weaving, as work that is only slightly laborious becomes impossible in a place where the wet bulb registers more than 25° C.
Fleicher, of Gottingen, is of opinion that the criterion of the injuriousness of the air is given by the dew point, that is to say, by the temperature to which the air should be brought in order that the aqueous vapour may be held in the air at maximum tension. This dew point lies between 12° and 13° C. and should never exceed 19° C., which corresponds to 85 per cent. of humidity at a temperature of about 21° C.

The experiments of Haldane have been confirmed by the English Cotton Cloth Factory Act of 1909, under this clause:

Between the reading of the dry and wet bulbs there shall always be maintained at least the following differences:

<table>
<thead>
<tr>
<th>Dry bulb</th>
<th>Difference between the dry and wet bulbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 29° C.</td>
<td>1°</td>
</tr>
<tr>
<td>From 21 to 25° C.</td>
<td>2°</td>
</tr>
<tr>
<td>Above 25° C.</td>
<td>3°</td>
</tr>
</tbody>
</table>

The temperature of the wet bulb shall never exceed 28° C.

Boulin considered that the best temperature is 24° C., which is not too low for the needs of the industry. In spinning and in certain weaving, for example, humid conditions are of more importance than anything. A prudent factory owner tries to maintain the same percentage of humidity whatever may be the temperature. It is, therefore, necessary in practice to deal with the temperature, technical conditions being opposed to any diminution of the necessary humidity.

In conclusion, in order to improve the hygienic conditions of a workshop, it is necessary to arrange for the critical temperature not to be exceeded or, if that is impossible, to modify one of the factors which assist in fixing that temperature in such a way as to make it rise only slightly.

Boulin has remarked that to reach the end sought for, it is not possible for technical reasons to make a variation in the deficit of saturation, a fixed deficit of saturation being necessary for each thread and for each manipulation. If then the hygrometer is useful from the technical point of view, it is in the case in question at least superfluous in the matter of hygiene.

In the case where the critical temperature is reached or passed, it may be inopportune to cease work or to cease artificial humidification. In certain places, especially in summer, when the outside temperature exceeds 30° C., it is impossible not to exceed 24° C. wet bulb if the relative humidity must be raised inside. It is, then, very rare that the ventilation or the humidifying system adopted will enable the temperature of the workroom to be lowered more than 3°. Under these conditions Boulin makes the following two recommendations:

(a) In workrooms of the textile industry where artificial humidification is carried out, when the thermometer rises to 24° C., a system by which the air is renewed at least twice an hour must be established. The air should be drawn from the outside, or, if technical considerations do not allow it, then either wholly or partially from the interior.

(b) In the same workrooms and under the same circumstances as in the combing of wool, and workrooms adjoining, where heat and moisture arise from the manipulations which are carried on there, arrangements must be made in summer to prevent the entrance of solar heat rays. Pipes which convey steam should be coated throughout with efficient non-conducting material wherever it is not indispensable that they should be left uncovered.

As regards mist, this must, according to A. Turin, be removed by heat combined with ventilation, which, except in special cases, should be mechanical. The amount of air sent in will be important and must be calculated by taking into account all the considerations examined. Mechanical ventilation should be by propulsion. The current of air should be suitably introduced at a height of 2.50 metres so as not to inconvenience the workers. It can be carried out by using open fans, or by a shaft—which should, however, be avoided as much as possible. The temperature of the atmosphere must not exceed 20° C.

Utilisable heat, save in exceptional cases, is that contained in steam allowed to escape, or from a high-pressure boiler, and better still from a specially constructed low-pressure boiler. The heating apparatus should be capable of being regulated; it should for preference be placed outside the workroom or at its entrance, and groups of heating radiators should be constructed by which the air can advantageously be heated.

The withdrawal of humid air must be effected by aspiration, or by free openings specially constructed and of a calculated capacity.

It may be said that a test of the efficiency of an installation for desaturation is to be able, under the most unfavourable conditions, to see 20 metres ahead in the workroom.

Atmospheric humidification should be carried out in such a manner that the phenomena reported among persons
remaining in hot and moist places are not to be feared. It is also essential to maintain the necessary hygroscopic degree whilst renewing the air.

An exhaustive study has been made of the problem, with special consideration for the case of industries which require at the same time a fairly high temperature.

The reasons for which most of the fibre textiles require a moist atmosphere are known. But in certain processes, as, for example, work with the yarn of flax, hemp, and cotton, in preparation for the weaving process, a moist atmosphere is required without the need of a high temperature.

It is not necessary to build to-day, as in the past, workrooms with limited apertures, thick walls, and low ceilings.

At the beginning the means taken to ensure the removal of excess of moisture were the same as for steam; large workrooms, well aired, supplied with louvred ventilators in the upper part, or with hoods linked up to collecting ducts, or the two systems conjointly.

But it was soon found that these costly means were not only inoperable, but actually encouraged the formation of mist, for the arrival of saturated air at a lower temperature into air already saturated at a fixed temperature favoured the formation of the mist, just as when a saturated atmosphere is cooled.

It is clear that in these workrooms with louvred ventilators and a large roof surface difficult to warm, the walls and ceilings are, especially in winter, always colder than the saturated air above the vats, and cause in consequence the formation of mist which they should have prevented.

The results are better when the removal is effected by shafts placed above the vessels containing the hot water. But this means is also insufficient, for the moist air leaving by the shaft causes a strong back draught of outside air which is generally colder. This air comes in contact with the saturated air at the level of the water and causes the formation of fresh mist, while the walls run with moisture.

The value of a ventilating shaft is increased by placing above it a chimpey set so that its action does not depend on outside conditions.

A method employed by certain factory owners, which consists in shutting off completely the space between the vat and the hood, presents several disadvantages; the workman is liable to leave open any sliding shutter, which only ought to be open during actual work in connection with the vat; further, work goes on without any supervision; and, finally, it is not possible to apply this scheme to movable tanks, or to those of small size, or when the work is carried out with two.

Elevation of temperature, in order to prevent condensation of aqueous vapour, is only a makeshift. That scheme can only act for a very short period, for, if removal of moist air is not assured and if the heat is distributed uniformly in the workroom, the air will very quickly become saturated at the new temperature. Next, the new temperature must be raised, when after a short time a saturated atmosphere at great heat is established, which is more harmful to the workers than the mist at a low temperature.

It is necessary, then, to insure the entry of fresh air which will not cause new condensation of mist, and this is effected by admitting air which is far from its point of saturation and capable of dissolving a fresh quantity of condensed moisture. The effect obtained is so obvious that English workers say, "the steam is eaten by the hot air".

In conclusion the problem may be solved theoretically by two methods: (a) by warming the air admitted into the workrooms, which is the method most employed; (b) by first drying the air by passing it over hygroscopic substances. In certain cases the air can also be admitted at a low temperature.

A third method consists in preventing the formation of mist by ensuring that the air never becomes saturated. In this case warm air is admitted, which replaces that removed by the hoods arranged over the hot water tanks.

Only by mechanical ventilation can renewal of air be calculated with any accuracy, the temperature in the workshop be fixed with certainty, and the entry of fresh cold air be prevented.

The exhaust system, which produces in the workroom a slight negative pressure, can be useful if the workroom is well closed and if the windows are few. Exhaust fans are placed at the ceiling of the place, causing an oblique current of air, which enters through openings placed at the bottom of the wall opposite the fans. The air, passing over radiating surfaces heated by steam, is warmed to the desired temperature; it then passes into the room where it meets the saturated air,
causes a desaturation and is removed by the exhaust fans.

In certain particular cases, for example, dyeing vats, direct exhaust over the vats has been tried, but this system has many disadvantages.

The plenum system has on the contrary several advantages: it creates a slight pressure which opposes the entry of cold air, at least at the upper and middle zones. The warmed air should be introduced into the workrooms at a suitable height, which has been carefully studied and may be between 2.50 and 3 metres. Ventilation which is not annoying to the staff can be easily obtained, amounting to six to eight times the volume of the workroom.

Air may be introduced immediately into the workroom, or directed at a desired height and distributed by sliding panels or special fittings. These last must be as simple as possible, and be capable of being regulated, the object being to distribute the warm air in the desired amount at each place. Moreover, the area allotted to each air-distributing duct or tube should be calculated exactly.

The ducts have fallen into disfavour as the result of experience, and some factory owners have tried to introduce warm air directly into the workroom by constructing groups of air-heating ventilators, a certain number of which are distributed in the workroom and pass in the hot air direct (noticeable even at 15 metres) with the ventilators only open a few millimetres at an angle of little more than 15 degrees.

Finally, plenum and exhaust can be used at the same time, so that the warm air follows a horizontal movement. The result may be exact that if the volume of air dealt with by the exhaust fans is sensibly less than that allowed for by the ventilators and if the building is well closed up in the vicinity of the exhaust fans.

Turin recommends putting in the system without fixing definitely the removal of air, so as to reserve the possibility of modifications, e.g. by opening the window sashes. He further holds that it is better to allow the moist air to escape by openings of sufficient size in places determined beforehand and rectified afterwards, if required, after trial, and without exhaust.

In the particular case of mist forming in great quantity at a well-defined point, Turin suggests avoiding its extraction, but dispersing it by heat supplied by a coil of galvanised pipes placed above the centre of its formation.

It has been seen that, in a moist atmosphere, electricity produced by textile fibres rubbing against the parts of the loom disappears in a conducting atmosphere with advantage to technique.

In practice efforts have been made to replace the necessary warm humidity by currents of high frequency. The first applications were made about 1911 by Ducretet upon looms for weaving wool in region of Fourmies, France. These currents discharge the electricity from the textile fibres and allow good weaving without excess of heat or moisture. But the trial period cannot be considered as closed.

In the same way the fight against excess of steam in the atmosphere, which condenses in a mist when the point of saturation is reached, can be carried on by the help of air heated by an electric heater. It is not too much to hope in the future, as Bar- geron says, for electrical dispersion of mist and perhaps dehumidification of atmospheres charged with mist.

LEGISLATION

Legislation provides for the prohibition of work in places which are too moist, especially if underground work is concerned. Measures have been enacted for preventing the escape of steam into the atmosphere of a workroom when humidity is not necessary. When, on the contrary, humidity is necessary, regulations provide that processes shall be carried on without too much injury to the health of the workers. Hence legislators have laid down very detailed regulations for unhealthy trades, such as the textile industry, paper works, and laundries (see the relative articles).

BIBLIOGRAPHY


Air (Liquid)


Air is a mixture of oxygen (23 per cent. by weight) and nitrogen (77 per cent. by weight) containing very small quantities of argon, neon, helium, krypton and xenon. These elements are also found in liquid air.

Liquid air is colourless, but with a bluish reflection, and has a density of about 1; its boiling point is between $-19.5^\circ$ C, the boiling point of nitrogen, and $-182.5^\circ$ C, the boiling point of oxygen. To be preserved, liquid air must be protected against heat and for this purpose silver vessels with double sides within which a vacuum is created are used (Dewar vessels, similar to "thermos" flasks).

In spite of its very low temperature, liquid air only rarely causes lesions of the skin. As a matter of fact the hand can be dipped into liquid air without harm. This immunity is due to the formation of an insulating gaseous layer; it is the phenomenon of calefaction.

Liquid air is excellent for supporting combustion owing to its high concentration of oxygen.

Air cannot be liquefied by compression, its critical temperature being $-140^\circ$ C. But the lowering of the temperature caused by the expansion of compressed air is used.

Linde's machine, which is used for the liquefaction of air, is constructed as follows: (a) a triple compressor which compresses air to 200 atmospheres; (b) a purifier containing lime and potash, which removes from the air the moisture and carbonic acid which it contains; (c) a freezing chamber constructed of concentric coils. Compressed air circulates downwards in the interior coil, then it cools itself by expanding. The expanded air rises in the annular space created between two coils. Thus it abstracts heat from the compressed air, which is within the interior coil and is cooled before expansion. In this way a number of successive coolings are obtained, which enables a sufficiently low temperature to be rapidly reached. The liquid air is gathered together in a collector situated at the lower part of the freezing chamber.

The machines of Hampson and of Heylandt are based on the same principle as that of Linde. In the machine of Claude the air when expanding is made to do work. The cooling is thus greater. This machine possesses much the same parts as that of Linde, but it includes in addition a cylinder furnished with a piston. It is true that the expansion of the air occurs, which then passes through the tubes of the freezing chamber. The cylinder and its sliding valve are lubricated by liquid air.

Uses

Liquid air is used for the preparation of explosives of the type "oxylignite", frequently used for piercing tunnels. A cartridge of liquid air, or, better still, of liquid oxygen, is made up of a paper tube enclosing absorbent materials: soot, sawdust from wood, wood dust, etc., combined or not with metallic powders, such, for example, as aluminium. This cartridge is perfectly inert and only acquires its explosive properties after being dipped in liquid air. The oxygen evaporates fairly rapidly and the cartridge becomes again completely inert at the end of about half an hour. In practice, the explosive cannot be utilised for such a long period. The explosion should occur when the quantity of oxygen and the combustible material of the cartridge are in such proportions that combustion of this material can occur without setting free carbon monoxide which would be injurious in the atmosphere of a mine. Cartridges of 38 mm. diameter by 300 mm. in length should be used with a delay of ten to fifteen minutes. The metallic powders are intended to increase the explosive force.

Liquid air is further used for respiration apparatus, life-saving apparatus used in mines, respiration apparatus for balloons and aeroplanes, and in scientific laboratories where liquefied gases are manipulated.

Most of the liquid air produced industrially is distilled in apparatus comprising columns in tiers similar to
those used for the rectification of alcohol.

Thus oxygen is obtained, the uses of which are numerous; nitrogen, which is used in the manufacture of ammonia (see that article) and calcium cyanamide (see that article); argon, used for filling incandescent electric lamps (see that article) and neon, used for making red-coloured luminous tubes with rarefied gas.

Montlaur (Paris) reported in 1926 that a jet of liquid air received on the back of the hand by him set up erythema followed by numerous phlyctenae. He considers that liquid air is not without danger when coming in contact with the bare skin.

Another accident occurred in the course of evaporation of large quantities of liquid air to obtain crypton and xenon present in the last stages, the reservoir exploding and killing the engineering chemist in charge of the operation (1926).

Claude considers that the accident was due to the presence of impurities and particularly to traces of acetylene and ozone.

An apparatus for production of liquid air transforms 1,000 cub. m. of air per hour; should the air, as a result of the liberal use of acetylene for soldering and lighting, contain one part per million at the end of the month, there would be a kilo of liquid acetylene in the apparatus, which would form with the liquid oxygen a very powerful explosive mixture. Claude is therefore of opinion that only very high layers of the atmosphere should be liquefied in order to ensure that no traces of acetylene are included.

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Air of the Workroom
(Close Air, Vitiated Air)


In many factory workrooms there are special hygienic hazards of the first importance created by the presence of toxic fumes or of siliceous dust. These problems are discussed elsewhere under various headings — see articles "Gas and Fumes", "Stone Industry", "Dust", "Tuberculosis", etc. — and this article is confined to changes in the atmosphere due to human occupancy and to the combustion of illuminants, that is, to the conditions which obtain in the ordinary workroom where no special poisons or industrial dusts are generated.

Composition of Air

Normal outdoor air is composed of approximately 78.1 per cent. of nitrogen by volume, 20.9 per cent. of oxygen, 0.9 per cent. of argon, 0.03 per cent. of carbon dioxide, and small proportions of other gases such as neon, helium, krypton, and xenon. In addition to these substances, which are relatively constant in their proportions, there is present a variable amount of water vapour. The maximum amount of moisture which the air can retain in gaseous form varies widely with the temperature. Thus air at 0° C. will hold only 4.8 grm. of water vapour per cubic metre; at 20° C., 17.0 grm.; and at 30°, 29.9 grm. In view of this fact, the amount of moisture present is commonly expressed not in terms of absolute volume, but in terms of relative humidity — the ratio of the water vapour actually present to the amount which the air could hold at its actual temperature if saturated.

Factors of Vitiation

As a result of the vital processes of the human body or of the combustion of ordinary illuminants (both processes being essentially similar oxidations of organic matter), five changes are effected in the air of an occupied room. The oxygen is decreased, the carbon dioxide is increased, the temperature and moisture are increased, and there are added to the atmosphere certain incompletely oxidised substances, often of an odorous nature. In the case of the human body the latter type of materials includes the products of organic decomposition discharged upon the skin by the sweat glands and the sebaceous glands (valeric, butyric and caproic acids, methylamine, trimethylamine, etc.) : the results of putrefaction of organic substances accumulated through lack of cleanliness of the surfaces of the body and the clothing or arising from the mouth and teeth, and products originating in the digestive canal (intestinal gases, ammonia, hydrogen sulphide, indole, skatol, fatty acids, etc.). It is such products which give to the air of an unventilated room its characteristic "body odour:"

Former Theory

Taking up, one by one, these five changes in the atmosphere produced by human occupancy, the decrease in oxygen which takes place in an ordinary unventilated room was shown by Lavoisier in 1777 to be without
practical significance; and in 1868 Pettenkofer showed that the increase in carbon dioxide was equally unimportant. In the deep parts of mines where carbon dioxide has largely replaced oxygen, or at high altitudes where the partial pressure of oxygen has been reduced in similar degree, men actually suffer from oxygen starvation. In the worst ventilated rooms on the earth’s surface, however, the natural ventilation through cracks and diffusion through the actual substance of walls and ceiling is so great that oxygen never falls below 20 per cent. and carbon dioxide rarely rises above 0.5 per cent. Such changes as this are far below the threshold of physiological significance.

Pettenkofer himself believed that the effect of bad air was due to hypothetical organic poisons associated with the products of decomposition which give rise to the body odour, and that the object of ventilation was the removal of these poisons by dilution with fresh air. To Pettenkofer, carbon dioxide was of significance as an indirect measure of the presence of morbific matter, and it is to him that is owed the assumption that air containing less than a certain amount of carbon dioxide is good and air containing more than a certain amount is bad. Brown-Séguard and, in later years, Weichardt, Trillat, and Henriet have been the chief exponents of the theory of atmospheric “morbific matter” in various forms.

Modern Theories

The great majority of physiologists, however, now accept the view that the harmful effects of bad ventilation (apart from the presence of industrial poisons and industrial dusts) are no more the result of hypothetical organic poisons than of changes in concentration of oxygen and carbon dioxide. They are due to the other two effects of human occupancy, increase in temperature and moisture, combined with lack of air movement — conditions which, in combination, produce a serious interference with the heat-regulating mechanism of the body. As far back as 1833, Hermans of Amsterdam, arrived at the conclusion that the harmful effects of bad air were due not to its chemical but to its physical properties, and in 1905 Flogge and his associates at Breslau definitely and clearly formulated the modern conception of ventilation — a conception expressed by Professor F. S. Lee in the succinct formula that the problem is essentially physical, not chemical, cutaneous, not respiratory. The conclusions of Flugge have been amply and universally confirmed by Hill and Haldane in England and by Benedict and the New York State Commission on Ventilation in the United States.

In one form or another these various investigators have shown that a group of subjects enclosed in an experimental chamber and suffering from the familiar effects of bad ventilation can in no way be relieved by permitting them to breathe fresh outside air admitted through a tube, but can be completely relieved by cooling the vitiated air of the chamber in which they are imprisoned. The only effects which can be definitely traced to chemical vitiation are slight interference with appetite and with the inclination to physical work, due to the psychic effect of body odours. These latter effects, however, only appear, with a concentration of some 20 parts per 10,000 of carbon dioxide, equivalent to an air change of some 11 cubic metres per person per hour, and are entirely subsidiary to the thermal influences which constitute the major problem of ventilation.

Effect of Increased Temperature and Relative Humidity

On the other hand, all recent work has tended to emphasise the very serious effects of even slight degrees of overheating upon the physiological state. The human body produces by its vital activities from 100 to 400 calories of heat per hour, depending upon the extent of physical exertion. This heat is given off to the surrounding air at a rate which would normally vary very widely with the temperature of the atmosphere. Yet, by one of the most complex regulative mechanisms of the human body, these processes are so beautifully balanced that the actual body temperature does not vary in health more than a degree on either side of the normal (36.5° C.).

At low temperatures this regulation is in part, but only in small part, accomplished by an increase in heat production; at high atmospheric temperature there is no such adaptation, the heat production within the body being actually though slightly increased. It is, then, the rate of heat loss which varies and which is the chief factor in maintaining the body temperature at a fixed level. When in a hot room, the tiny blood vessels of the skin expand (as is the face becomes flushed) said, and bring a large
amount of blood to the surface of the body to be cooled off. On passing into cold outside air, the skin blood vessels contract, the blood is sent into the inner organs, and the cooling effect of the air upon it is thus correspondingly reduced. This is the chief regulatory process which operates at atmospheric temperature below 10°. As the temperature of the air rises a new factor enters: the increased production of sweat, which is evaporated (if the air be not too humid), with the absorption of heat which always accompanies the change of a liquid to a gaseous form.

The primary effect of high atmospheric temperature is, then, to dilate the tiny blood vessels of the skin and thus concentrate the blood flow in them at the expense of the inner parts of the body. In part, the feeling of discomfort and lassitude experienced is probably due directly to anaemia of the brain and other internal organs caused by a reduced flow of the blood in the capillaries. Furthermore, as will be pointed out below, habitual exposure to such conditions leads to a lowered tone of the whole heat-regulating mechanism and an inability to respond to the demands which may be put on it, and in this way exerts a profound and important influence upon susceptibility to respiratory infections. With only slightly excessive atmospheric temperature, the body temperature of the subject rises, the heart rate and the respiration increase, and the Crampton index—a measure of the efficiency of the vapor motor system—falls to a significant degree. The performance of physical work is markedly affected. In the New York State Commission studies, 28 per cent. less work was accomplished at 30° C. as compared with 20° C. even under conditions of maximum effort, and in a test where the subjects were influenced only by a small bonus, a temperature of 24° C. showed 15 per cent. less work performed than was accomplished at 20° C., a conclusion of the most far-reaching importance as an argument for the regulation of temperature in the workshop and factory.

Finally, the work of Hill in England and of the New York State Commission in America has indicated profound effects of only slight degrees of overheating upon the prevalence of respiratory disease. In the studies conducted by the New York State Commission on 2,500-3,000 school children during two successive winters, it appeared that a room temperature averaging 20.3° C., as compared with a room temperature averaging 19.1° C., showed an 18 per cent. excess of absence due to respiratory disease and a 70 per cent. excess of respiratory disease among pupils in attendance. Both English and American observers find the explanation of this effect in observable changes in the membranes of the nose and throat due to overheating and in consequent inability to resist the change from heat to cold on passing into the outdoor air.

At still higher temperatures symptoms of course become much more acute. The United States Bureau of Mines, in an extensive series of studies recently carried out at Pittsburg, Pa., equipped a carefully controlled experimental chamber in which subjects, variously clothed, under a very wide range of temperatures, humidities, and degrees of air movement and prolonged exposure to high temperature to the point at which a longer stay appeared definitely dangerous. Restlessness, irritability, headache, and palpitation of the heart, soreness of the eyes, a sensation of oppression on the chest, dizziness, and confusion were the chief symptoms experienced; and weakness and a dragged-out feeling persisted for some time after such experiments had closed. The extreme dry-bulb temperature which could be endured was 69° C. (wet-bulb temperature 38° C., relative humidity, 15 per cent.) for forty-five minutes while the extreme wet-bulb temperature was 44° C. for thirty-five minutes. The body temperature under such conditions rose several degrees. The pulse rate seemed to be the best measure of discomfort, 135 beats per minute corresponding to marked discomfort, and conditions becoming almost unbearable when the pulse rate exceeded 150 beats. With moderate overheating, both systolic and diastolic blood pressures fall; under more extreme conditions systolic blood pressure increases while the diastolic pressure continues to decrease.

Curiously enough, the increase in respiration rate observed by the New York State Commission and by Vernon in England was not noted at Pittsburh. Marked rise in body temperature and pulse rate were, however, apparent above 32° C. in saturated air. One of the most important contributions of these investigators is the recent report that basal metabolism (the rate of oxidation within the body) decreases with increasing temperature up to about 26° C. (with 100 per cent. relative humidity) and then increases, the rise becoming very rapid when the atmos-
phic temperature is higher than that of the body. Such a temperature of 26° C. with 100 per cent. relative humidity (corresponding in its physiological effects to about 31° C. with 50 per cent. relative humidity in still air or 34° C. with 20 per cent. relative humidity in still air) is clearly a critical temperature beyond which serious harmful results may be expected. Ideal conditions were found to lie between 17° and 21° C.

**VENTILATION STANDARDS**

Official administrative standards of ventilation are still generally based on the older chemical theory rather than the newer thermal one. According to the Pettenkofer conception, a concentration of carbon dioxide in excess of 6 parts per 10,000 was supposed to be associated with a dangerous proportion of poisons in the air; and standards advocated by more recent authorities vary from 6 to 10 parts.

On the assumption of such a carbon dioxide standard it is course very simple to calculate a standard of per capita air supply. Since it is known how much carbon dioxide is eliminated by an average individual per hour, the dilution of this carbon dioxide by outside air containing 3 parts per 10,000 so as to keep the room air below a given concentration is merely a matter of arithmetic.

In addition to Pettenkofer's standard there should be mentioned the "anthracometric standard", which has for its aim to stress the importance of renewal of air in confined spaces and which measures such renewal by charging the atmosphere with artificially produced CO₂ and determining the content at stated intervals. The system is as follows: CO₂ is liberated in a confined space till a given percentage (approximately) of the gas is present—the percentage in question being a fairly high one. The liberation of the gas having ceased, after a lapse of time the CO₂ content is taken in order to provide an estimate of the rate of renewal due to ventilation.

Another method consists in liberating carbon dioxide at a constant rate throughout the whole experiment and by taking the content, on two successive occasions separated by a given lapse of time, to ascertain the variation in the percentage present in the air (P. Bellon).

Leclerc de Pulligny and Boulin have studied a formula for calculating the vitiation and the cubic capacity of rooms:

* If an individual exhaling 0.02 cubic metres of carbon dioxide per hour is placed in a room the cubic capacity of which is C cubic metres while the renewal rate of air per hour is V cubic metres, the outer air containing 1/10,000 of carbon dioxide, the time at the end of which the content of the room in CO₂ will reach N is expressed in hours by the following formula (1):

\[
t = \frac{200}{V} \log \left( \frac{C}{200} - \frac{N - n}{V} \right)
\]

(1)

* This content has moreover an upper limit 10,000/10,000 which it approaches indefinitely without however attaining it and which is expressed by the formula (2):

\[
t = \frac{200}{V} \log \left( \frac{C}{200} - \frac{N - n}{V} \right) = 0
\]

(2)

* On the other hand the CO₂ content rapidly reaches the value N which it approaches indefinitely which differs from the maximum only by 1/10,000 and the time t, at the end of which this content is attained is expressed by the formula (3):

\[
t = \frac{200}{V} \log \left( \frac{C}{200} - \frac{N - n}{V} \right)
\]

(3)

In practice, these experts state, "it is equation (2) which is used for calculating the renewal of air V independent of the cubic capacity per person, required, to maintain the vitiation below a given limit N, and when it is desired to ascertain the length of time after which vitiation has reached approximately 1/10,000 recourse will be had to equation (3). If it is desired that, without renewal or with slight renewals V, the maximum vitiation tolerated 1/10,000 (N = 10) should not be attained after a period of four hours, the values of C which should correspond to each value of V will be got from equation (1). Taking N = 3 (3/10,000 carbon dioxide present in the outer air), there is found:

<table>
<thead>
<tr>
<th>Cubic capacity per person (in cubic metres)</th>
<th>Cubic capacity per hour in cubic metres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cubic m.</td>
<td>Cubic m.</td>
</tr>
<tr>
<td>15</td>
<td>80</td>
</tr>
<tr>
<td>10</td>
<td>93</td>
</tr>
<tr>
<td>6</td>
<td>105</td>
</tr>
<tr>
<td>3</td>
<td>114</td>
</tr>
</tbody>
</table>

which rate is considerably higher than the minimum cubic capacity per head of 7 metres provided by legislation, and which in certain cases is judged as difficult of attainment.

* For a renewal of 28.5 cub. m. the vitiation of 10/10,000 is precisely the limit which is never attained. For a cubic
capacity of 7 metres that of 9/10,000 is reached after 28 minutes. 48 seconds.
A renewal of 28.5 cub.m. is that which must be considered as normal. Further, it is essential that the fresh air introduced should be well distributed throughout the workroom.
The time at the end of which vitiation reaches 10/10,000 is calculated by applying equation (1) and the values will be as follows:

<table>
<thead>
<tr>
<th>Cubic Meters</th>
<th>Minutes</th>
<th>Seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>25</td>
<td>12</td>
</tr>
<tr>
<td>15</td>
<td>20</td>
<td>48</td>
</tr>
<tr>
<td>10</td>
<td>18</td>
<td>—</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>1</td>
</tr>
</tbody>
</table>

### The Standards Adopted

From an ideal point of view, each worker should be accorded a surface space of 2 metres and a cubic capacity of 5 metres with an hourly exchange per capita varying according to the nature of the work effected, but never falling short of six times per hour for a sedentary worker and ten times for a worker engaged in active physical exertion.

Though formerly health experts demanded a renewal of air which varied between 6-10 cub.m. per capita per hour (Leblanc), 8-12 (Peclet), 10 m. (Arago) and 38 m. (Offermann) or 54 (Parkes), to-day the average value demanded is 30 per capita per hour (see article "Ventilation").

### Legislation

All legislative systems in the industrial countries contain regulations the purport of which is to prevent workers from being allowed to follow their occupation in unduly close air. It is however important not only to set limits as to cubic capacity, but at the same time to regulate the surface space and the hourly renewal of air per head.

Though in a minority of legislative provisions a vague and indefinite formula is still used, such for instance as "adequate cubic capacity proportionate to the number of workers and in accordance with hygienic requirements", most legislative provisions now cite a minimum value for cubic capacity and even for air renewal. Thus, for example, Austria demands a cubic capacity of 10 cub.m. and a surface space of 2 metres which are subject to increase should certain circumstances render it necessary (dust, fumes, etc.); Belgium also demands 10 cub.m. per worker and a renewal of 30 cub.m. at least per hour and of 60 cub.m. in specially unhealthy workshops; Canada requires 11 cub.m. per worker; Denmark 8 cub.m. (which the Factory Inspection Department may increase to 12); France demands 7 cub.m. at least and 10 cub.m. in certain industries (laboratories, kitchens, stores, shops, and public offices). The air must be renewed in such a way as to maintain the standard of purity essential to the health of the workers (Decree of 10 July 1913), and the general ventilation for any enclosed space shall be such as to prevent an undue increase of temperature.

In Great Britain 7 cub.m. is demanded as a minimum: further the Cotton Factory Act and other Orders impose a maximum of 9/10,000 of CO₂ for the textile industries with a cubic capacity of 11 metres when overtime is worked unless electric light is installed. In Italy the draft regulations for industrial hygiene provide for a uniform cubic capacity of not less than 10 m. per person as well as a minimum surface space of 2.50 metres. Air in closed workrooms shall be frequently renewed so that the CO₂ rate produced by exhalation shall not exceed 10 in 10,000. Where this rate is exceeded factory inspectors shall have authority to demand that natural ventilation be completed by artificial ventilation. Whatever the system of ventilation, all draughts liable to inconvenience workers must be avoided. The air of workshops must be renewed at a fixed point and exceeding a rate of 0.50 per second must be avoided. In Holland, good natural ventilation must be provided where mechanical ventilation is not installed. Natural ventilation is deemed insufficient where the local surface of aperatures communicating directly with the outer air is not at least 5 cub.decametres exclusive of doors. The third part at least of the surface of such apertures must be situated at a minimum of 1.80 m. above the ground and it ought to be open independently of all other apertures demanded by legal requirements. Sweden demands 10 cub.m., and Switzerland likewise with a minimum height for workrooms of 3 metres, etc.

A whole series of values are provided for the various industrial operations more especially as regards the work of women and young persons. (See also article "Workrooms").

### Criticism and Suggestions

All of these legislative standards in the light of more modern views as to the objectives of ventilation now appear to be more or less obsolete, or at least very incomplete. Ventilation is to-day primarily conceived as a means for removing the excess heat produced by the human body and replacing it by fresh air that is cool but not too cold. The amount of air needed for this purpose will obviously bear no necessary and direct relation to the number of persons in a given confined space unless the opportunity for direct heat loss through windows, walls, and ceiling be also taken into account.
Under certain conditions, as for example in an interior auditorium with no appreciable heat loss, the standard of 70 cub. m. per hour (legally required for schools in many American States) will prove substantially correct. An average adult gives off approximately 100 calories of heat per hour, and this is almost exactly the amount of heat necessary to raise the temperature of 70 cub. m. of air from 16° to 21° C. In factory workrooms where there are special heat sources such as forges, furnaces and annealing ovens, the amount of air necessary to maintain good ventilation may be materially more than this. In certain annealing shops for example, 30 changes of air per hour have been effected with notably successful results. On the other hand, where the room is relatively small and has one or more outside walls the necessary air change may be materially less.

The standards cited above, of 30 to 50 cub. m. of air supply per hour are, however, very moderate even on the basis of thermal considerations, corresponding roughly, as they do, to 10.5 parts and 8 parts per 100,000 of CO₂ respectively. An air change of this extent will generally be needed in order to remove the heat produced by the human body and to avoid the accumulation of body odours which are offensive, even if not dangerous to health. It is by no means sufficient, however, to supply a given volume of air to the factory workroom. The main essential is temperature control, and a room with only 30 cub. m. of air supply per person per hour at a temperature of 19° C. is far better than one with 100 cub. m. at 22° C.

The temperature is of course only one of the conditions affecting heat loss from the body. Humidity and air movement must always be kept in mind as two factors in the problem.

The influence of atmospheric humidity upon heat loss from the body is quite different at different temperatures. If the air temperature be low, there will be little or no discharge of perspiration and the body will lose heat chiefly by direct conduction and radiation to the surrounding atmosphere. Moisture in the air tends to produce a deposit of moisture on the clothing, and moist clothing conducts heat more readily than dry clothing. Hence, very moist cold air seems chillier than dry cold air. This condition obtains up to a dry-bulb temperature of about 4° to 10° C. Above 10° C. the secretion of sweat begins and the cooling effect of the evaporation of this sweat becomes more and more important as a factor in heat loss the higher the temperature. Under these conditions the cooling influence of conducting moisture is outbalanced by the fact that moisture in the air interferes with the evaporation of perspiration. Because of this interference with evaporation, moist, warm air is far more uncomfortable than dry air at the same temperature.

Air containing only 20 per cent. relative humidity at 21° C. is about as comfortable (according to the Pittsburg figures) as saturated air at 18° C.

The third factor in determining the physiological effect of a given atmospheric condition is the extent to which conduction, or evaporation, or both, are favoured by the movement of the air. In a still atmosphere the body is surrounded by a layer of air which has been rendered hot and moist by the heat and moisture given off by it and it is this hot moist air to which the surface of the body is actually exposed.

The Pittsburg studies indicate that the conditions tabulated below are roughly equivalent to each other from the standpoint of human health and comfort.

**SUMMARY OF ATMOSPHERIC CONDITIONS PRODUCING AN EQUAL COOLING EFFECT UPON THE CLOTHED BODY**

<table>
<thead>
<tr>
<th>Dry-Bulb Temperatures (Centigrade)</th>
<th>Relative humidity</th>
<th>Rate of air movement, per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
<td>30 m.</td>
</tr>
<tr>
<td>20 per cent.</td>
<td>90.3</td>
<td>91.4</td>
</tr>
<tr>
<td>50 per cent.</td>
<td>96.2</td>
<td>97.3</td>
</tr>
<tr>
<td>100 per cent.</td>
<td>97.2</td>
<td>98.6</td>
</tr>
</tbody>
</table>

Relative humidity is measured by the wet-bulb thermometer and the cooling effect of air movement is estimated by the katathermometer (see article “Air: Hot and Humid”). Except where humidity is produced by special industrial processes or where air movement is greatly increased by artificial ventilation, the ordinary thermometer is a reasonably close measure of indoor atmospheric conditions.

The thermometer should be an essential part of the equipment of every workroom, and whenever the temperature rises above 20° C. steps should be taken to remedy the condition by turning off heat sources or opening windows or by the installation of the secretion of artificial systems of ventilation. That such attention to temperature regulation will bring
sample results in diminishing absenteeism due to illness and in increasing working efficiency is amply demonstrated by the New York State experiments cited above and by practical industrial experience reviewed in another place (see article "Ventilation").

BIBLIOGRAPHY
See article "Ventilation".

Prof. C. E. A. Winslow
(U.S.A.).

Air: Testing in Workrooms
French: Air des ateliers (Contrôle de l'). — German: Luftuntersuchung der Arbeitsräume. — Italian: Analisi dell'aria dei locali di lavoro. — Spanish: Control del aire de los talleres.

Medical men are often called upon to decide, during claims for compensation, the responsibility for casualties caused by the escape of noxious gases, poisonous dust, and the like. The question of the healthiness of the air of workrooms is important, but it is also most complex. It is expedient to act promptly and whenever possible to carry out an analysis of the air on the spot by methods which, even though sometimes empirical, are none the less useful. It is even essential from the hygienic point of view, without waiting for a casually to occur, to carry out periodical analyses of the atmosphere in places where unhealthy processes are carried on. Slow poisoning by carbon monoxide, or by an atmosphere strongly charged with various impurities, often remains unrecognized, or is only found out when serious symptoms have already developed. Troubles of nutrition, anaemia, neuritis, jaundice and other serious symptoms are too often among working workers without definite cause, when in reality the condition should be attributed to the unhealthy atmosphere.

A definition of normal air is required. Its average composition is: from 20.50 to 20.80 volumes of oxygen per 100 volumes of dry air, from 79.47 to 79.17 of nitrogen, and from 0.03 to 0.07 of carbonic acid, argon and neon, etc.

Normal air is odourless and has a humidity of from 60 to 150 (in volume) per 100 (0.005-0.010 per litre) and 1 to 100 of pollution.

The quantity of carbonic acid must be determined and also the reducing power (degree of pollution); but in reality the degree of pollution and the quantity of carbonic acid are two independent variables, and the quantity of carbonic acid has been claimed as sufficient by itself for giving precise indications of the degree of closeness and even of the injurious nature of the atmosphere. The requisite measures for ventilation or aeration required to bring the strength of carbonic acid within the generally admitted limit, which for workplaces is 6 parts per 10,000, can be rapidly estimated.

Ventilation and aeration must not be confused: to aerate is to ensure a sufficient cubic capacity; to ventilate is to remove by appropriate means foul and injurious vapours and prevent any risk from their inhalation. Gases of poisoning by gas occur even in the open air, for want of suitable ventilation.

ESTIMATION OF CARBONIC ACID

The method of Pettenkofer may be here recalled. Into a five-litre flask containing the air to be analysed there is poured 100 cub. cm. of a baryta solution (1 litre of water, 5 grm. of pure barium hydroxide, 0.2 grm. of barium chloride). After shaking for half an hour, it is allowed to settle and 25 cub. cm. of the clear liquid floating on the top is withdrawn, made alkaline and titrated with a titrated solution of oxalic acid (1.12 grm. of oxalic acid and a sufficient quantity of distilled water to bring the solution up to a litre). The diminution in alkalinity gives the amount of carbonic acid by the quantity of oxalic acid used, since 1 cub. cm. of the oxalic acid solution corresponds to 0.25 cub. cm. of CO₂ at 0°C and 760 mm. of Hg.

Baryta water is to be preferred for absorbing carbonic acid; it absorbs it completely, even with a simple wash bottle, and even if the current of air is fairly rapid. Further, as the carbonate of baryta is deposited very quickly at the bottom of the wash bottle, the amount of carbonic acid can be watched and followed, while the sample is gradually being taken, and even estimated approximately, using certain simple precautions, by reading the height of the deposit. With this object it is sufficient to graduate the bottom of the wash bottle. This preliminary estimation will always enable the moment for stopping the test to be determined; it should

1 It is better with a solution of soda and potash, provided that the surrounding temperature does not fall too low and remains about +10, without which it is preferable to use a solution of equal volumes of soda N/3 and baryta water prepared as at +5. In case of very great cold, soda is employed without baryta. Under these conditions, the factors for the calculation of carbonic acid are different.
be the moment when the deposit formed is sufficient for an accurate estimation.

The rapidity with which the baryta water becomes clouded is in proportion to the amount of carbonic acid in the air. Thus, when aspirating at a rate of three litres an hour, 5 cub. cm. of baryta water placed in an ordinary wash bottle, either Cloez pattern or some other, become densely clouded:

- in twenty minutes if the air contains 5 parts per 10,000 of CO₂, which is about normal;
- in ten minutes if the air contains 1 per 1,000, as in confined or suspected air;
- in less than two minutes if the air has 4 parts per 1,000, which may be considered bad air.

A deposit of carbonate suitable for accurate estimation will be obtained at the end of the following times:

- in one hour if the air has 5 parts per 10,000;
- in thirty minutes if the air has 1 per 1,000;
- in ten minutes if the air has 4 per 1,000.

For making an estimation some drops are added of a mixture containing equal parts of alcoholic solutions of 1 per cent. phenolphthaline and helianthine; then it is titrated direct with N/4 nitric acid until two successive colour changes occur, shaking up the air meanwhile as much as is necessary to keep the liquid stirred.

The first change from red to clear yellow occurs at the moment when all the free baryta is neutralised; the second change from yellow to rose, when all the carbonate has been neutralised in its turn. The volume of nitric acid necessary to pass from one colour to the other indicates the carbonic acid and that alone 1 in the proportion of 0.0055 grm. CO₂, or about 2.80 cub. cm. for each cub. cm. of nitric solution 2.

**ESTIMATION OF OTHER ACID GASES**

The process mentioned above allows of direct estimation not only of carbonic acid, even if mixed in the atmosphere with other acid gases, but also of these latter.

1 Except when the air contains excessive traces of sulphuretted hydrogen, without reaction upon the helianthine; but it is easy to guard against this cause of error which would certainly not pass unnoticed.

2 If, in place of baryta, a solution of soda alone is employed, 1 cub. cm. N/4 used for titrating is the equivalent of 5.60 cub. cm. of CO₂; this method is not so sensitive; further, amongst other disadvantages there is that of no chromatic reaction being set up.

When it is a case of dealing with ordinary air, more or less confined, this distinction is scarcely of importance, for acid gases in addition to carbonic acid, are not found in appreciable quantities. But it may be otherwise in the case of so-called industrial emanations.

Following upon the estimation of carbonic acid, that of other acid gases is direct, depending for the purpose on a knowledge of the initial alkalinity of the baryta water used. It is then sufficient to subtract from the alkalinity which has disappeared that which has been definitely absorbed by the carbonic acid. Thus is ascertained at once whether the atmosphere contains other acid gases or not.

Here are the details of a test:

<table>
<thead>
<tr>
<th>Rate of flow of air</th>
<th>1 litre in 20 min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of baryta water</td>
<td>10 cub. cm.</td>
</tr>
<tr>
<td>Volume of air aspirated</td>
<td>4 litres</td>
</tr>
</tbody>
</table>

**Alkalinity of baryta water expressed in cub. cm. of N/4 nitric acid:**

<table>
<thead>
<tr>
<th>Initial</th>
<th>After test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st with phenolphthaline</td>
<td>16.60</td>
</tr>
<tr>
<td>2nd with helianthine</td>
<td>16.70</td>
</tr>
</tbody>
</table>

**Correction for CO₂ pre-existing in the baryta:** 0.1 cub. cm.

**RESULT**

| Total alkalinity absorbed by the acid gases | 0.90 cub. cm. |
| Alkalinity absorbed by carbonic acid | 0.90 cub. cm. |
| Acid gases other than CO₂ | nil |

**Volumetric strength of the air in CO₂:**

\[
\frac{0.90 \times 2.8}{4} = 0.63 \text{ cub cm.} \\
\text{or 6.3 per 10,000.}
\]
Several types of portable apparatus are in existence for rapid tests. Kohn-Abrest uses a metal vessel, with a zinc body and a copper lid, of a capacity of five litres, which, with its accessories, can be carried in a kind of portable cupboard. The air is aspirated by a water flow through flat Cloez flasks 1, independent one of another and arranged in series on a copper fixture to which they are connected by metal tubes with taps (see fig. 5). The fitting unscrews and allows the vessel to be refilled. Each flask is removable and ready for instant replacement. The best speed of aspiration corresponds to 120 or 140 bubbles per minute. The volume of air aspirated is given by the level N.

Generally there are four flasks for each fitting. Two ordinarily suffice for testing the healthy state of an atmosphere: one of them gives the strength of carbonic acid and is eventually also used for testing for and estimating the quantity of other acid gases, and also by means of a special arrangement for testing for carbon monoxide; the other verifies the absence of other injurious gases.

A process has also been suggested based on the time required to decolorise a drop of potash or baryta solution of a fixed concentration coloured by phthaline. The baryta solution keeps a long time; it is enclosed in sealed glass ampoules. When needed for use, the point of the ampoule is broken and the coloured solution is made to flow into a drop counter, which facilitates the deposition upon filter paper of the drops of liquid necessary for determining their time of decoloration in the polluted atmosphere. The same principle can be applied to an arrangement for testing for carbonic acid by the passage of a fixed volume of the air to be tested (Hébert-Heim).

For rapid estimation of amounts of carbonic acid, Hébert and Heim use a "carbicidometer", by means of which by passage of a definite quantity of air, the carbonic acid is fixed by means of potash in a wash bottle or in a sealed tube; the carbonic acid is then set free in an apparatus resembling a calcimeter, an apparatus used in agricultural chemistry, and measured exactly.

Other methods have been employed: thus, for example, Cristiani, of Geneva, has devised an apparatus composed essentially of a small bore wash bottle, containing 1 cub. cm. of a standardised solution of carbonate of soda coloured with some drops of phenolphthalein, into which the air to be analysed is passed. After having previously collected the air in a flask, it is displaced into the wash bottle by introducing into the flask previously boiled water from a graduated vessel. In the wash bottle the air gives off its carbonic acid which at a certain moment decolourises the solution. It then suffices to read off the number of cubic centimetres of water introduced, which represents the cubic centimetres of air sufficient to neutralise 1 cub. cm. of the solution. A simple calculation gives the amount of carbonic acid.

Lehmann recommends absorption in three batteries of Lunge tubes with ten

---

1 Flat wash bottles of a capacity of 15 to 20 cub. cm.; internal diameter of the vertical tube, 3 mm.
Haldane has designed a portable apparatus which enables the amount of carbonic acid to be determined on the spot. The method consists essentially in direct observation of the diminution in volume of a given sample of air resulting from the absorption of carbonic acid by a solution of potash. The air is introduced into a burette by lowering a reservoir of mercury, which is connected to it by means of an indiarubber tube. The volume of air required (25 cub. cm.) having been introduced, the tap for the entrance of air is closed; the sample of air is then made to pass into a wash bottle containing potash by raising and lowering the reservoir. After complete absorption of the carbonic acid the volume of the sample is again observed. The difference found between the first and the second reading gives the quantity of carbonic acid absorbed.

**ESTIMATION OF CARBON MONOXIDE**

Although for this investigation the blood process may be the best (see article "Carbon Monoxide"), by the help of a container an estimate may be made of the presence of carbon monoxide, which, if not extremely accurate, at least indicates its absence in proportions exceeding 1 part in 10,000.

For this purpose there must be adjusted to the ground glass mouth of one of the wash flasks (see fig. 5) on the supporting fixture, a tube of bent glass containing iodic acid, which can also be used for the detection of this gas in the atmosphere is described elsewhere (see article "Carbon Monoxide").

A standard portable apparatus has been recently suggested by Sayers and Yant (1924).

**ESTIMATION OF OTHER GASES**

The absence of most other gases may be determined by the aid of 5 cub. cm. of a mixture of a slightly acidulated solution of silver nitrate N/100, i.e. 1.7 grm. per litre, and of permanganate N/500, i.e. 0.006 grm. per litre.

When after aspirating 2 litres of air the solution remains rose coloured and does not show any turbidity, the absence...
of injurious gases in pronounced quantities may be presumed. This indication should nevertheless be confirmed by more precise tests, carried out by the aid of a series of wash bottles charged with appropriate absorbing reagents.

The reagent is prepared exactly in the following manner:

Solution A: nitric acid, 50; potassium permanganate 3 grm.; water sufficient to make up to 1,000.

Solution B: water 1,000; silver nitrate 3 grm.

A little before use, mix in the following proportions:

\[
\begin{array}{c|c|c|c}
A & 1 \text{ cub. cm.} & B & 20 \\
\text{Nitric acid} & 1 & \text{Water} & 50 \\
\end{array}
\]

This reagent, formerly recommended by Merpeix as a test for carbon monoxide which decolorises it, but not with any great sensitiveness, appears on the contrary sensitive to other injurious gases, which equally produce decoloration, and, according to the particular gas, will give white precipitates (in the case of cyanogen and hydrocyanic acid up to 1 per 5,000).

The presence of cyanogen seems important from the toxicological point of view, for it may be that minute traces of hydrocyanic acid, detected in the viscera of persons who have succumbed to the effects of illuminating gas, have no other origin.

**Situation of Certain Hydrocarbons**

The apparatus just described permits the person responsible for the healthiness of any atmosphere to test also for all the other poisonous gases. All he needs do is to provide himself with the reagents required for each particular case.

Among the industrial processes which are suspect from the point of view of the healthiness of the atmosphere where they are carried on, must be mentioned trade processes which bring into use solvents of india-rubber, fatty bodies, and acetate of cellulose such as benzene, carbon bisulphide, and chlorine derivatives of hydrocarbons, particularly tetrachlorethane. It is important that in these workrooms there should be no perceptible smell, the chemical test being then reduced to its most simple expression, for the absence of smell implies, as has been confirmed experimentally by Lehmann, the absence of quantities, excessive from the hygienic point of view, of harmful vapours of these solvents.

\[1\] Up to the present, however, tests for hydrocyanic acid in the blood of such cases have remained negative. It is, however, possible that investigation by extra sensitive processes may enable traces to be found.
Nevertheless, the estimation of traces of the aforementioned vapours can be easily made.

In the case of benzene, the air is aspirated using an empty four-litre flask (Vigreux, Liebig, Willim, but the last named uses a wash bottle of very small size) containing some cubic cm. of fuming nitric acid. An aspiration of twenty litres of air at the rate of about three litres an hour is sufficient.

Nitric acid, being diluted with water, according to the classic method, nitrobenzene appears in the form of a cloud, or, according to the amount, is precipitated in globules. The liquid is neutralised with soda which causes a characteristic odour; it is digested with ether, after separating from the ether by decanting and filtering through dry paper; it is evaporated either in the air; this last is saponified after a time and the chloride formed is estimated; the absence of free halogenes or their hydracids must be assured, or, if they exist, taken into account.

With an apparatus "for rapid testing" and an arrangement for detecting carbon monoxide, all the materials necessary for testing the salubrity of the air are at hand.

Nevertheless, it will be convenient in certain cases to provide oneself with a shallow box containing four dry flasks, empty of air or gas, of a capacity of four litres. These flasks are far preferable to india-rubber bags when it is a case of testing for all sorts of gases, such as chlorine, and even carbon monoxide or carbonic acid, which diffuse rapidly through india-rubber. A metal manometer shows cold or on a stove at 37° C. (free from humidity) and the residue weighed. In this way a tenth of a milligram of benzene per litre of air can easily be detected (1 part of nitrobenzene corresponds to about 0.6 of benzene, \( C_6 H_6 \)).

If the air is suspected of containing carbon bisulphide; the wash bottle is charged with an alcoholic potash solution; the solution of xanthate of potash is acidulated by acetic acid and precipitated by sulphate of copper.

The alcoholic solution of potash also allows qualitative and quantitative tests for traces of tetrachloroethane in the air; this last is saponified after a time and the chloride formed is estimated; the absence of free halogenes or their hydracids must be assured, or, if they exist, taken into account.

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The attention of the expert will be chiefly focussed on escapes of the products of combustion, carbonic acid and carbon monoxide, and directed to the question of fumes. It is known that the production of carbon monoxide during combustion is most irregular and that it is scarcely possible to foresee the quantity of this gas which may escape into the atmosphere. The escape depends, among other factors, on the quality of the coal and also on the method of stoking. It would evidently be an advantage from the hygienic point of view only to employ, so far as is possible, fuel of a uniform type, such as coke, unless the more combustible gases, which are given off by raw coal on distillation, are used.

In order to show exactly how, in spite

**Fig. 9. — Bottles emptied of air by manometer.**
of all calculations, the production of carbon monoxide may remain undetected, some experiments have been made by Kohn-Abrest on a stove, of a pattern much used by the people of Paris, which acts at will either as an ordinary stove, or for slow combustion. All these experiments were conducted either with a brisk or a slow fire, on days when the atmospheric conditions varied very little and fuel was chosen intentionally from different kinds of coal, particularly from coal with very little gas, i.e. close burning coal, but rich in carbon, in fact allied to anthracite, and by contrast from coal very rich in gas, i.e. bituminous, or so-called house coal, resembling coal as extracted before being graded.

The numerical results of analyses of products of combustion taken in the pipe of the stove about a metre from the orifice of the discharge were as follows:

1. Brisk Fire (Normal Draught)

<table>
<thead>
<tr>
<th>Constituent gases</th>
<th>Illuminating gas</th>
<th>Naphthaline</th>
<th>Petrol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonic acid</td>
<td>17.75</td>
<td>10.29</td>
<td>12.29</td>
</tr>
<tr>
<td>Oxygen</td>
<td>2.86</td>
<td>10.04</td>
<td>3.17</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>traces</td>
<td>0.20</td>
<td>1.96</td>
</tr>
<tr>
<td>Hydrocarbons</td>
<td>none</td>
<td>none</td>
<td>traces</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>none</td>
<td>none</td>
<td>traces</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>79.89</td>
<td>79.54</td>
<td>82.55</td>
</tr>
</tbody>
</table>

2. Slow Fire (Reduced Draught)

<table>
<thead>
<tr>
<th>Constituent gases</th>
<th>Illuminating gas</th>
<th>Naphthaline</th>
<th>Petrol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonic acid</td>
<td>10.58</td>
<td>9.57</td>
<td>12.93</td>
</tr>
<tr>
<td>Oxygen</td>
<td>6.08</td>
<td>7.10</td>
<td>3.45</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>1.90</td>
<td>1.33</td>
<td>0.90</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>none</td>
<td>none</td>
<td>traces</td>
</tr>
<tr>
<td>Nitrogen, etc.</td>
<td>81.54</td>
<td>81.80</td>
<td>81.72</td>
</tr>
</tbody>
</table>

It is sufficient to examine these figures closely to find how they show unexpected and apparently contradictory facts as regards the production of carbon monoxide. It will be seen that the amount varies in the different experiments, even when, all the other conditions being equal, the quality of the fuel itself is not changed. Without insisting further, it may be stated that in the absence of the discovery of any fixed law, these experiments show that the most prudent course, whether the combustion be quick or slow, is to discharge outside by a good chimney all the products of combustion.

**INTERNAL-COMBUSTION MOTORS**

The gases which escape from petrol motors are very rich in carbon monoxide, even more so than those from lighting gas itself: they are troublesome from the viewpoint of economical combustion, and troublesome, if not dangerous, from that of health.

An internal-combustion engine can rapidly make the atmosphere of any place into which the exhaust gases escape fatally dangerous.

Samples of gas taken from the interior of the exhaust pipe of several types of internal-combustion engines give the following results:

<table>
<thead>
<tr>
<th>Constituent gases</th>
<th>Illuminating gas</th>
<th>Naphthaline</th>
<th>Petrol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonic acid</td>
<td>3.90</td>
<td>16.01</td>
<td>18.55</td>
</tr>
<tr>
<td>Oxygen</td>
<td>7.83</td>
<td>0.86</td>
<td>3.35</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>6.19</td>
<td>0.43</td>
<td>0.41</td>
</tr>
<tr>
<td>Carburetted hydrogen</td>
<td>none</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Formic acid</td>
<td>traces</td>
<td>0.92</td>
<td>0.92</td>
</tr>
<tr>
<td>Acetylenic acid</td>
<td>traces</td>
<td>0.78</td>
<td>0.78</td>
</tr>
<tr>
<td>Acetylic monoxide</td>
<td>none</td>
<td>traces</td>
<td>traces</td>
</tr>
<tr>
<td>Nitrogen estimated by difference</td>
<td>88.17</td>
<td>82.70</td>
<td>77.41</td>
</tr>
<tr>
<td>Index of toxicity</td>
<td>It = 0.025</td>
<td>0.0275</td>
<td>0.022</td>
</tr>
<tr>
<td>CO₂</td>
<td>13.97</td>
<td>2.018</td>
<td>1.42</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>82.34</td>
<td>81.72</td>
<td>81.80</td>
</tr>
</tbody>
</table>

These figures indicate that a considerable part of the petrol is wasted in certain internal-combustion engines, since, independently of carbides not burnt, it is found that in the combustion products the proportion of carbon monoxide is greater than that of carbonic acid. The result clearly indicates that in every instance the toxicity of these exhaust gases is great; herein lies the explanation of certain serious casualties.

As regards naphthalene engines, while they have other serious faults, they seem to use their fuel better.¹


Even in the open air, all trouble is not avoided, for it is known that when the atmosphere is calm, sheets of gas form which only diffuse very slowly into space. This is the reason why certain countries prohibit, at least at certain hours of the day, motor-cars from passing along somewhat enclosed roads.

**Gas Apparatus**

The products of combustion from gas fittings have been the subject of a number of investigations, especially of carbon monoxide.
concerning incandescent fittings, either upright or inverted.

Kling and Florentin, for example, have found that the production of carbon monoxide in upright incandescent burners is extremely variable, depending on the makes.

It is as high as five litres of CO per 1,000 litres of gas burnt in certain types, whilst in other Auer burners the production of carbon monoxide is very slight.

With inverted mantles it is on the contrary always high, even if they are supplied with synthetic gas free of CO; it frequently reaches eight and even ten litres of carbon monoxide per 1,000 litres of gas burnt. These results are disputed by other experts, but it is probable that the contradiction is only apparent.

It is evident that in calculating the proportion of carbon monoxide per 100 litres of gas burnt, and in taking into account the make of the burner, results are arrived at which seem to differ much from those where the proportion of carbon monoxide existing in the air of the room is alone referred to.

Moreover, it is for this reason that Kohn-Abrest considers it advisable always to refer to the production of carbon monoxide per unit of gas burnt, and, in a general way, only to take into account the relation between the carbonic acid produced and the carbon monoxide (index of toxicity).

An index of toxicity of illuminating fittings, of heating apparatus and of internal-combustion engines (relation CO/CO₂) has been proposed by Kohn-Abrest to enable a rapid determination to be made of the hygienic value of every means of using fuel of whatever kind.

Just as in metallurgy, the custom is, in order to keep under observation the steady working of blast furnaces, only to take into account the relation between the volumes of carbon monoxide and carbonic acid produced by combustion, so it is no more necessary in these circumstances to trouble about the exact spot where the sample is taken.

Sampling.—Two flasks each of a capacity of four litres with ground-in stoppers are fitted with tubes provided with taps. A vacuum having been first obtained, the two flasks are connected together and filled by aspiration with the same sample of air. In many cases, however, flasks of two litres, and even of one litre are used.

<table>
<thead>
<tr>
<th>CO₂</th>
<th>CO</th>
<th>Index of toxicity CO/CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>460-365</td>
<td>650-765</td>
<td>0.33 to 1.40</td>
</tr>
<tr>
<td>109-88</td>
<td>152-185</td>
<td>—</td>
</tr>
<tr>
<td>30-30</td>
<td>370-440</td>
<td>12.3 to 14.0</td>
</tr>
<tr>
<td>1,470</td>
<td>0.00 to 19</td>
<td>0.00 to 0.013</td>
</tr>
<tr>
<td>1,550</td>
<td>180</td>
<td>0.14</td>
</tr>
<tr>
<td>1,200</td>
<td>196</td>
<td>0.16</td>
</tr>
<tr>
<td>1,000</td>
<td>85</td>
<td>0.065</td>
</tr>
<tr>
<td>15 to 30</td>
<td>65-100</td>
<td>4.3 to 3.0</td>
</tr>
<tr>
<td>530</td>
<td>0.8 to 3.7</td>
<td>0.0015 to 0.007</td>
</tr>
<tr>
<td>535</td>
<td>0.8 to 7.0</td>
<td>0.0015 to 0.013</td>
</tr>
<tr>
<td>590</td>
<td>0.8 to 11.1</td>
<td>0.0015 to 0.0213</td>
</tr>
<tr>
<td>480-360</td>
<td>24-180</td>
<td>0.05 to 0.5</td>
</tr>
</tbody>
</table>

**PRODUCT IN LITRES OF CO₂ AND CO**

**Relation of CO/CO₂**

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>CO₂</th>
<th>CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bunsen burner</td>
<td>110</td>
<td>530</td>
</tr>
<tr>
<td>Simple furnace</td>
<td>190</td>
<td>535</td>
</tr>
<tr>
<td>Fish-tail burner</td>
<td>110</td>
<td>590</td>
</tr>
<tr>
<td>Radiators</td>
<td>350 to 500</td>
<td>480-360</td>
</tr>
</tbody>
</table>

La production de l’oxyde de carbone par les bras à incandescence, in Chimie et Ind. et Industrie, 1921; and, previously, Comte Rendu Acad. Sc. T., 169, 1914, p. 1404.
The most valuable kinds of calcareous alabaster are those of Cairo, Algeria, Mexico, and Italy; of gypseous alabaster those of Italy, Greece, Great Britain, Germany, etc. The most important quarries for gypseous alabaster are to be found in Tuscany (Volterra, Pisa, Leghorn, etc.). The method of working and the maladies from which the miners suffer have been studied closely by Pieraccini, Giglioli, and Mori.

Only such details will be given here as are not stated in the article "Stone Industry".

**SOURCES OF DANGER**

Generally speaking, alabaster quarries are underground and extend ten and even a hundred metres below the level of the sea. The galleries are very long; sometimes the striking face is two kilometres from the entrance. Ventilation is bad, especially if there is but one entrance. Lighting is insufficient and even totally absent except for illumination obtained from acetylene lamps. Temperature varies according to the season (from 15° to 30° C.). Humidity also varies from one quarry to another — indeed very often much water accumulates in the galleries, and even at the entrance, generally situated on the banks of a stream (especially during floods). Sometimes the humidity rate reaches 70 per cent. No toxic gases are evolved, but the atmosphere is often vitiated by excess of carbonic acid gas emitted by the men, the lights, etc., and this is rendered worse by defective ventilation.

Transport of the blocks of alabaster is fatiguing from 20 kilos to several quintals (10-12). Rough shaping is practised on the spot (at the face) because it is a delicate operation.

**PATHOLOGY**

Alabaster dust, according to Giglioli, is injurious to the respiratory tract, setting up fairly severe lesions: this writer refers to workers with defective chest development, feeble health, respiratory diseases (75 per cent. being tuberculous), and suffering from haemoptysis apart from tuberculosis. Some authorities do not consider the dust injurious because it contains no silica, and Pieraccini, for example, questions it as the cause of the damage. He thinks it injurious not on account of its quality, but rather its quantity, aided by the sedentary life of the workers. De Hieronymis has studied the death rate from tuberculosis in the province of Pisa and in the town of Volterra, finding the mortality figure low for the general population of

**Alabaster**


**PROPERTIES**

Two kinds of alabaster of different chemical composition exist: calcareous alabaster or calcite (CaCO₃), which is a kind of calcium carbonate, and alabastrite, which is a sulphate of calcium or gypseous alabaster (CaSO₄·2H₂O).

One part of the sample serves for the estimation of carbon monoxide and the other for that of carbonic acid (atmospheric CO can be deducted quite easily). Kohn-Abrest shows the advantage of using as an aspirator a system consisting of a flask (No. 1) identical with that (No. 2) in which the air is sampled. A vacuum is first made in the aspirator, which is then put in communication by suitable tubing with the baryta wash bottle, the other tubing of which is connected to flask No. 2.

On carefully opening the taps of the flasks, air is drawn bubble by bubble through the baryta till the pressure in the two flasks is equalised. At this stage it is known that half the volume of air in the flask has washed through the baryta. Less air can also be aspirated and, in order to know the volume, the pressure in flask No. 2 is measured and used made of the formula \( V' = \frac{V}{H} \), where \( V' \) is the initial volume under the pressure \( H \) of the gas sampled. As a general rule \( H \) is only the atmospheric pressure, \( V' \) the volume remaining, \( H' \) the pressure in flask No. 1 at the end of the test (fig. 9).

The preceding table gives some interesting indices of toxicity *, and shows that for petrol motors the figure is extremely high; for acetylene motors the formula \( V' \) is two kilometres from the entrance. Ventilation is bad, especially if there is but one entrance. Lighting is insufficient and even totally absent except for illumination obtained from acetylene lamps. Temperature varies according to the season (from 15° to 30° C.). Humidity also varies from one quarry to another — indeed very often much water accumulates in the galleries, and even at the entrance, generally situated on the banks of a stream (especially during floods). Sometimes the humidity rate reaches 70 per cent. No toxic gases are evolved, but the atmosphere is often vitiated by excess of carbonic acid gas emitted by the men, the lights, etc., and this is rendered worse by defective ventilation.

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Volterra, which town is well situated, and high for the workers in question. He is led to enquire if it is the dust which is responsible or rather the life led by the workers, since, in view of the fact that the tubercle bacillus is absent from Volterra, the dust cannot be said to favour infection. Mori is of the same opinion; he recalls that the workers are rejected from military service because of their poor chest development, short stature, and feeble physical constitution; but morbidity from broncho-pneumonia, gastro-enteritis, etc., is not greater among them than among other workers.

Rheumatism, on the other hand, is common and is probably due to the rapid change from a hot, humid internal atmosphere to the colder outside air, and common, too, are maladies due to chill (pneumonia, rheumatism, etc.). The abundant white dust which covers the miners from head to foot, making them resemble millers, is the cause of a diminution of the vertebral column: a scoliosis with a concavity of the spine. A scoliosis with pronounced hypertrichosis.

Accidents are not characteristic; a great many are caused by the tools, especially by the rubbing and polishing alabaster. Amongst alabaster workers working at the lathe an occupational callosity has its seat on the external third of the upper surface of the right clavicle.

**Legislation**

In France young persons under 18 years of age are prohibited from sawing and polishing alabaster dry if dust is given off freely. In Spain boys under 15 years and females under 21 are prohibited from rubbing and polishing alabaster. In Italy employment of boys under 15 and females under 21 is prohibited.

See also the article "Stone Industry".

**Bibliography**


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**Alcohol (Intoxication by)**

**Alcoholism**


Magnus Huss, a Swedish medical man, was the first (in 1853) to employ the term "alcoholism" to describe the effects produced by intoxicating drinks which depend on multiple agents—some chemical (the kind of drink), others biological (constitution of the individual), and others again social (environment).

The drinks producing these effects are obtained by fermentation (beer, wine) from sugary vegetable substances and have been known from time immemorial; others obtained by distillation (brandy, rum, whisky) are much more dangerous and of more recent introduction. Although men have been addicted to alcoholic drinks from remote times, alcoholism only commenced to spread after Arnoldo of Villanova in the thirteenth century discovered the formula for making *aqua vitae* or brandy.

Alcoholism, making steadily increasing progress for several generations, is a racial malady which may be considered to-day to have reached its culmination.

**Toxic Action**

Alcoholic drinks act: (1) by their content in ethyl alcohol, which varies according to the products absorbed; (2) by the impurities and essences they
contain (higher alcohol: propyl, butyl amyl; ethers, aldehydes), the effects of which vary — some inebriating, epilepticiform, others convulsive, tetanic and anaesthetic.

The distinction which it has been attempted to make between wine-drinking and alcoholism is open to criticism, because between ethyl and the higher alcohols there is only a slight difference in the degree of toxicity.

Alcohol acts after absorption by digestion and inhalation. Without calculating the long series of researches made, there is no doubt that alcohol ingested has no physiological properties. Only in the most restricted sense can it be held to be a food, and its energy-producing value is very rapidly counter-balanced by the toxic properties which manifest themselves on absorption of only a small quantity.

Empiricism and subsequent experience have shown that alcohol is equally toxic on inhalation. Orfila, indeed, intoxicated dogs, and Strauss rabbits, by way of the lungs. Sand found that inhalation of a mixture of alcohol and ether administered drop by drop to dogs set up, after a period free from symptoms, excitement, convulsions, etc. Killed five months after inhalation of the mixture the dogs showed specific lesions: haemorrhage and stasis in all the organs especially marked in the liver, kidneys and nervous system.

Authorities disagree as to the quantity of alcohol an adult in good health can consume with impunity, this quantity varying according to the physical and normal state of the individual, age, sex, constitution and temperament, heredity, state of health or disease of the various organs, individual resistance, mode of life, environment, occupation, and nature of the beverage absorbed (kind, composition, and proportion of alcohol in it). Alcoholic beverages do not usually produce their habitual baneful effects under the influence of moderate fatigue, of an open-air life, of exercise — conditions under which alcohol occasionally ingested can be consumed. Habit and custom produce a kind of mithridatism and in certain morbid states (diabetes, hysteria, dipsomania) unbelievable quantities of alcohol can be consumed.

According to Pouchet, for an average sized normal adult, neither under nor over developed, say for a man weighing 65 kg., 6 grm. per kg. may be a fatal dose; that is, 390 grm. of pure alcohol (corresponding to 850 or 900 grm. of brandy). Antheaume has determined the weight of living substance which can be killed by a litre of an alcoholic beverage:

<table>
<thead>
<tr>
<th>Beverage</th>
<th>Kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure ethyl alcohol</td>
<td>64</td>
</tr>
<tr>
<td>Martinique rum</td>
<td>64</td>
</tr>
<tr>
<td>Cognac (50 per cent.)</td>
<td>65</td>
</tr>
<tr>
<td>Brandy (Burgundy)</td>
<td>68</td>
</tr>
<tr>
<td>Kirsch</td>
<td>64</td>
</tr>
<tr>
<td>Brandy (plum)</td>
<td>68</td>
</tr>
</tbody>
</table>

Todd has reported the death of a man who had drunk a litre of rum, and Taylor that of child after absorption of 100 grm. of pure alcohol. Gréhant states that 1 grm. of alcohol can be tolerated per kg. of body weight, with a mean daily consumption varying from 50-70 grm., which corresponds to half a litre of vin ordinaire taken in the day. Maurel, of Toulouse, on the other hand, does not go beyond 40-44 grm., and Bianchi limits himself to 200-300 grm. of wine per meal.

Whilst diluted alcohol stimulates the functions of the living tissues with which it comes into contact, neat alcohol has an intense dehydrating and coagulating action on albuminoids; when insufficiently diluted it acquires anaesthetic properties, paralysing irritability, sensibility, contractility and the activity of the living cell.

The consumption of alcohol is very variable. In litres it is said to be per individual and country as follows:

<table>
<thead>
<tr>
<th>Country</th>
<th>Litres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finland</td>
<td>2.22</td>
</tr>
<tr>
<td>Norway</td>
<td>2.37</td>
</tr>
<tr>
<td>Switzerland</td>
<td>4.33</td>
</tr>
<tr>
<td>Italy</td>
<td>14.02</td>
</tr>
<tr>
<td>Spain</td>
<td>14.02</td>
</tr>
<tr>
<td>France</td>
<td>22.93</td>
</tr>
</tbody>
</table>

The countries consuming, by preference, wine are Italy, France, Spain, Portugal, Switzerland, Argentina, Uruguay, and Japan. Beer is principally consumed in Germany and by Anglo-Saxon peoples; liqueurs in Sweden, Norway, Denmark, Finland, Rumania, Austria, Hungary, and Russia; and whisky in Great Britain.

Physio-Pathology

Pathology will only be dealt with in its relation to occupation. An acute and a chronic intoxication may be distinguished: As has been already stated, these two intoxications are a double function of the kind of poison, of the quantity ingested, and of the soil into which it is received. Its evolution can take place with changes scarcely visible or, on the other hand, in a very rapid and complicated manner with subacute signs or acute paroxysms. There are a number of factors which are able to retard,
counteract or precipitate the appearance of acute phenomena or to hasten the evolution of the malady.

Without entering into details as to the pathology of acute or chronic alcoholism, it will suffice to recall that alcohol does not spare any organ, that it exercises a sclerotic and degenerative action on the tissues, and that it brings about the most varied morbid symptoms.

The nervous system is affected from the start, alcohol acting on the higher functions of the central nervous system as a narcotic. Sensory effects are early, and can be most readily observed in course of the victims' daily occupations. The poison exercises its pernicious action on the centres of perception - a fact which may have the most unexpected and formidable consequences. Many industrial accidents are due to the incompetence of drinkers whose senses have been dulled. Among visual troubles, dischromatopsia, central and paracentral scotomas, and diminution of visual acuity are noted. Railway companies provide for the withdrawal of alcoholic mechanics in whom a certain degree of Daltonism prevails, clear distinction of coloured signals. Among defects of hearing abnormal perceptions are to be noted: external sounds become exaggerated or discordant. The other senses are dulled and a sort of multisensory daltonism is created.

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Experience shows that many athletes who have imbibed alcohol to excess have died of phthisis; others have become insane. The assertion that intense muscular work can be done with greater impunity by resort to large doses of alcohol is false (Gréhan).

A great number of experiments by Destrées, Gilbaud, Chauveau, Galeotti, Herxheimer, etc., have shown how disastrous is the effect of the consumption of alcohol on muscular work.

In chronic alcoholism, the very slight, small, fibrillary tremor, sensible only to the eye when the hand is stretched out as the fingers held apart, suffices to destroy the manual dexterity of the worker.

Though tradition and popular prejudice incline to the belief that alcohol increases strength, it is none the less true that empirical observation has brought to light important facts which confirm scientific observations. In the ports of the Black Sea and the Bosphorus, the Turks, who are abstainers by religion, are engaged in carrying heavy loads, more especially coal, and this under a tropical sky; while they can stand the strain without difficulty for twelve hours the Rumanians, Bulgarians, and Wallachians have reached the limit of their strength after two or three hours and have to seek recuperation of their energy by resting.

The same proof has been given in the colonial services (e.g. the Indian army). The greatest explorers excluded alcohol from their daily diet (Livingstone, Nansen, the Duke of Abruzzi, etc.) and muscular force has been obtained from sugar rather than alcohol (experiments of Prantner, Stovasser, Mosso, etc.). In sport it is notorious how alcohol has been given up both during exercise as well as in rest time. Runners, swimmers, etc., the winners of great competitive trials try to remain abstainers. During the war all the Governments exerted themselves in a struggle against alcohol in order to keep up the energy of the masses.

**Alcohol and Physical Labour**

Physical exertion is impeded by consumption of alcohol, which excites and then depresses the nervous muscular system. Power to work after its absorption is only increased temporarily. The fact that for a time it stimulates muscular energy and causes fatigue to be forgotten accounts for the fact that certain individuals are willing to allow it to take the place of the material and moral satisfaction yielded by good living, instruction and education. In assuaging however the feeling of fatigue, it favours the onset of acute overstrain (from a state of febrile exhaustion to death by acute intoxication), or of chronic overstrain (physical wreckage favouring the development of morbid nervous or pulmonic affections).

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**Alcohol and Intellectual Work**

Alcohol diminishes intellectual work and, under its anaesthetic influence, the
mind becomes torpid, memory defective, fancy exalted, the senses dulled, the power of inhibition loses control and human personality gradually disappears.

The belief that alcohol is useful and leaves the higher functions unimpaired is wrong. Certain celebrated authors and artists may have been great drinkers, but it would be easy to cite others who have been temperate or abstainers. For some people alcohol may act as a stimulant, but nothing proves that to this is due the value of their work.

Before the stage of noisy manifestations of excitement is reached, consequences of the gravest importance from an occupational point of view may ensue.

The new habits as shown in the altered mentality of the drunkard, the weakened sensibility and moral dementia which appear rapidly, affect every aspect of mental activity (relations with himself, his people and with outsiders), and modify his social and occupational duties, his activity for work, power of production, and duties as a citizen. His mental deficiency shows itself early by modifying all that constitutes the normal acuity of mental activity: attention powers of reasoning, adaptability to circumstances. In the exercise of a daily occupation, where comparison is easily possible, drinkers frequently appear to be the laziest, sleepiest and dullest of the workers. They show less aptitude and skill in their actions, make mistakes, are forgetful, decide lightly, come to fantastic conclusions, etc.

[At the terminal stage of the malady, it should be remarked, hallucinations are entertained, a constant characteristic of which is that the victim believes himself back at his employment, thinks he is in the workshop, is foreman over his fellows, is doing his work, etc.]

Alcohol and Industry

The rôle that alcoholism plays to-day among workpeople cannot, and ought not to, be misunderstood; but account must be taken of the fact that certain conditions of labour tend too often to drive the worker to indulgence in drink, and so aggravate the lesions which the environment or the toxic products handled can engender.

The problem of alcoholism in its relation to industry should be examined from the point of view of the reaction (a) of alcoholism, as affecting the individual in the exercise of his occupation, and (b) of the occupation on alcoholism, the work serving to incite intoxication, which would then appear to be occupational. Having discussed the general effect of alcohol on physical or intellectual work, some further points remain.

Among chronic alcoholics distinction must be drawn between those who drink during working hours (during meals or in rest intervals) and those drinking only in their own time. In some trades where consumption of alcohol is forbidden during working hours, the persons employed often indulge in it during their free time.

There is no doubt that in these cases alcohol increases the harmful nature of certain occupational poisons. Thus, for example, the risk of work in high temperatures is notoriously increased by alcohol, favouring as it does the occurrence of heat stroke; it brings about earlier than would otherwise be the case a condition of fatigue, and has an unfavourable action on the heat regulating mechanism of the body, thus leading to a relative insufficiency of all the functions. Drunkards run an even greater risk in hot and humid atmospheres because in this case the evaporation of sweat and elimination of moisture from the lungs are interfered with by the high hygrometric condition of the air.

Alcohol is equally dangerous when working at low temperatures. Experienced alpine climbers know that alcoholic drinks induce a state of congestion, because though at first alcohol produces a feeling of warmth and well-being, as well as an increase of the peripheral temperature, it exercises rapidly thereafter, as a result of paralytic dilatation of the cutaneous vessels, a hypothermal action lowering the peripheral and central temperature and involving the possibility of passive congestion from cold. As a matter of fact, a fall of the central temperature to 30° and even 25° C. has been noted amongst drunkards.

Alcohol is also dangerous in compressed air work (caisson workers and divers), for which work young men who are abstainers are required. Experts and legislators agree in recognising that those addicted to alcohol or suffering from heart disease ought to be the first to be excluded from compressed air work, because of the risks to which they are exposed.

Chronic poisonings become aggravatgd when associated with chronic alcoholism, as a mixed intoxication is thus produced. Everybody recognises the influence of excessive drinking on the outbreak of lead colic, of gout, hysteria and saturnine epilepsy, as well as on
the mortality of workmen employed in lead industries.

Absence of data prevents reference to the joint effect of alcohol with mercury, carbon bisulphide, or opium, although there is no doubt that these poisons exert a very much more pernicious action on alcoholic subjects.

If liability to occupational poisoning is increased, and such poisons are also rendered more injurious by alcohol, they in their turn lessen resistance to alcoholic intoxication. Biondi and Giglioli have shown that workpeople suffering from mercury poisoning become drunk after consumption of a small glass of wine, and suffer from headache or giddiness after having smoked a cigar. Biondi has noted the same phenomena in a man employed in casting antimony.

The same facts hold in the case of acute intoxications.

The combined action of alcohol and aromatic compounds has frequently been described among T.N.T. workers in the explosives industry. According to Leymann, this is explained by the fact that the toxicity of all poisons soluble in alcohol (and little soluble in water) is increased by the consumption of alcohol. Nitrophenol, nitrobenzol, aniline, and many other poisons). In the case of aniline notably, it has been observed that persons who have worked for many years with this substance without showing ill-effects go under if they absorb large quantities of alcohol after their work is over. The probability is that aniline absorbed by the skin and lungs and set free in the stomach is dissolved by the alcohol and so enters the general circulation, or that the resistance to poisoning by aniline is diminished by the absorption of a small quantity of alcohol, or that the alcohol causes the latent poisoning to become manifest (Niggemeier and Chilian).

Thus it is that in all these unhealthy industries consumption of alcohol is forbidden during working hours, and the workers are well warned to abstain. Somewhat similar observations have been made in the case of calcium cyanamide, which renders the workpeople more sensitive to erythematous eruptions (copper itch).

In the same way, alcohol favours occupational cramp — particularly writer's cramp.

An enquiry made recently (1922) in Great Britain among navigation companies has revealed how alcoholism caused reduced efficiency among sailors.

Monday is the day of the week when the number of absences from work is highest. In some industries in France and Belgium absences were formerly so numerous that it was found not worth while to light the furnaces on Monday.

A question of the first moment is the relation of alcoholism to industrial accidents. The danger run by an alcoholic with the increase in machinery need not be insisted on. According to statistics of 800 accidents collected by the Ministry for Railways in Belgium, one-half was said to be due to alcohol. In France an average of 450 cases of accidents of one kind or another is due to the same cause.

Further, the particular nature of industrial work contributes to the occurrence of accidents amongst tipplers. Industrial work does not demand so much excessive muscular effort, as attention, agility, delicacy of movement and absolute mastery and control of oneself, which alcohol tends to slacken, diminish or suppress.

In spite of the undeniable fact of the influence of alcohol on accidents, and the numerous researches made both in the laboratory and factory, this influence cannot easily be expressed in figures. Though statistical analysis does not always yield satisfactory results, it can at any rate be concluded that.

(1) Chronic alcoholism would appear to be an important factor in the causation of accidents, alcoholics running three times the risk of abstainers or moderate drinkers. According to the statistics of the Leipzig Sickness Insurance Society, this is the case especially for the class of workers from 15 to 34 years and is proportionally highest in the group of severe accidents.

(2) Drunkenness properly so called is not frequently the direct cause of accidents at work principally because consumption of alcoholic liquors during working hours has lessened. About one-quarter of the total number of non-occupational accidents is attributable to drunkenness, occurring usually in the worker's spare time.

(3) Intemperance during work increases the risk of accident. Regulation of the sale of alcoholic beverages and the abolition of the practice of serving beer free of charge, so frequently practised, formerly, in some industries, has reduced the number of accidents by 30 to 70 per cent. In a German foundry the average number of accidents per 1,000 workmen, which used to be 32.8 when the free sale of drink prevailed (1897-1900), fell to 3.6 when this was regulated (1901-1904). Large businesses in America attribute to prohibition the fall in the number of accidents as much as 65 to 75 per cent.
Intemperance outside hours of work is the commonest form. But it is extremely difficult to estimate exactly its influence on industrial accidents. Statistics as to drunkenness on the different days of the week related to accident rates, whether general or occupational, seem to be most convincing. They regularly reach a maximum on Saturday and Monday. The statistics of Leprain and Picraccini show more especially that it is on Monday that intemperance on the Sunday takes effect. The co-efficient of accidents on that day is higher than on other days of the week with the exception of Saturday. Actual drunkenness on Monday, properly speaking, does not exist but rather its sequelae, of which the following are the most notable: disturbance of faculties and mental balance, inability to focus attention, dullness, reaction time prolonged, distaste for work, tremor, awkwardness.

Careful analysis, however, of Sunday's excess only partly explains the high accident rate and lessened output of the Monday.

On the other hand, regular drinking by the night shift, before going to the factory, shows itself in a high accident rate early on in their work.

It is by the gravity rather than the frequency of accidents that alcoholism exerts its most noticeable influence. The lesions set up by alcohol in the heart muscles, the effect on the heat regulating centre, the complications resulting from lesions or sickness of every kind which are so frequent in alcoholics, serve to explain the great tendency for cases to terminate fatally when an accident occurs or surgical interference is required. As experienced has shown that metamorphical repair processes are more irregular and slower in the brain of alcoholised animals, so also it is known that alcoholism retards the union of broken bones and proves a serious obstacle to recovery after any surgical or medical attention.

Drunkenness on the part of a workman may diminish or cancel employer's liability for compensation in the case of accident. Thus, for example, in France obvious intoxication of the workman constitutes the inexcusable fault provided for in section 20 of the Act of 9 April 1898 giving grounds for diminution in the pension. In certain countries persons indulging immediately in alcohol are excluded from certain work requiring accuracy of judgment (railways and navigation), whilst in other countries only abstainers are accepted for such work. Similarly certain industrial establishments forbid the use of intoxicating liquors, and others refuse all workers who are not abstainers.

Certain Swiss and British insurance companies accept a smaller premium from abstainers, while others refuse to accept drunkards.

Occupational Alcoholism

The numerous causes of occupational alcoholism can be reduced to two chief ones: need of stimulants and exercise of an occupation exposing to drinking habits.

Occupational alcoholism has certainly found, just as has general alcoholism, a suitable soil in the conditions under which modern industry has developed.

In the country, it is limited in the main to people in easy circumstances who seek to while away the time in inns. Certain circumstances, however, favour alcoholism and seasonal alcoholism can be spoken of as due to overwork and abuse of drink at the principal agricultural times (harvests, vintage, gathering of beet).

Allevi gives some Italian statistics (Amaldi) showing a high percentage of alcoholic psychoses among country folk. Without being able to quote exact statistics for other countries, alcoholism is well known to be widespread in the agricultural districts of France, Ireland and Poland.

Urbanisation is certainly a factor of the first importance in the spread of alcoholism. In towns, among the middle class temperance and abstinence are constantly on the upgrade. If this class furnishes a smaller number addicted to alcoholism than the proletariat, it is especially because they rarely are engaged in professions which make them take to drink. Nevertheless, chronic alcoholism is widespread in certain professions where it is customary to negotiate business in cafés (commercial travellers, wholesale merchants, etc.) or to spend time for pleasure there (officers, students).

As Montegazza has written, enumeration and classification of the drinkers of a country suffices to reveal the powerful influence that culture has over the taste for alcohol.

Among the labouring class, the taste for alcoholism may be partially attributed to the need to the worker of some distraction after his day's work. The effects of this need are increased sometimes by environment in the clubs and recreation halls where the workers meet and indulge in alcohol.
The narcotic effect of alcohol diminishes the sensation of distress brought on by work carried on under depressing conditions, and badly organised industries are especially those in which the largest number of workers take to alcoholic drinks. Long hours, Sunday work, speed of machinery, overtime, the monotony of modern work—all these have been frequently adduced as causes. An enquiry carried out in France (see Bulletin du Ministère du Travail, January to March 1923) shows the benefit derived from moving the population into the suburbs, from the development of workmen's gardens, the creation of popular libraries, and educational courses, increase in leisure, introduction of summer time, but, above all, the 8-hour day, which has done most to suppress the need for artificial stimulants during or after work.

Occupational alcoholism is met with particularly in certain industries or professions which may be said to predispose to the consumption of alcohol.

Though vinedressers do not show a high proportion of acute cases of intoxication (in the preparation of wine), they are sometimes exposed to poisoning by carbon dioxide (in the fermenting halls). On the other hand, almost all those whose livelihood depends on the sale of alcoholic beverages—and especially of spirituous liquors—are fataly addicted to intoxication, e.g. wine merchants, travellers in wine, butlers, wine tasters, distillers. Intoxication in such cases is the more dangerous because of its insidiousness, and from the fact that frequent alcohol taken in small quantities often brings on chronic alcoholism without any appearance at all of intoxication.

Of 44 men examined at the Laennec Hospital, Paris, Grandmaison found 22 wine merchants and potmen, and all were alcoholic.

Sometimes a genuine occupational alcoholism can be shown to result from the inhalation of alcoholic vapour. An individual who is sober but is obliged, owing to his occupation, to live in an atmosphere impregnated with alcoholic vapour can present all the toxic phenomena of ethyl poisoning from drunkenness (workers in distilleries, wine depots, customs house employees, etc.), especially when certain operations are carried on in a restricted, badly-ventilated place, with long hours of work. (Carozzi, in Italy, noted before the war that in certain liqueur factories the hours were 14 per day with four 1-hour intervals. Obviously, under these conditions even abstainers would finish by getting drunk.) Further, workmen in industries using alcohol may be cited in this connection—such as those employed in the making of felt hats, gunpowder works, manufacture of artificial silk, etc. In the smokeless powder and artificial silk industries, for example, mixtures of alcohol and ether are used, creating an intoxicating atmosphere. In these cases, the dangers of alcoholism can assume quite grave proportions.

Alcoholic excesses are more frequent in some trades and professions than in others, as recognised customs play an important role in the spread of habits of intemperance. Each trade has, in some district or other, a traditional form in which alcoholism shows itself.

Individual habit varies infinitely, especially in relation to the life which circumstances impose. The occupational environment (to some extent modified by educational influences), the social atmosphere and its customs, are tyrannical. Tipping for instance plays a definite part in the story of alcoholism, and similarly the manner of drinking, as e.g. gratuitous supply of drink (e.g. in breweries).

All jobs at high or low temperatures, and above all dusty work (mines and quarries notably) predispose to alcoholism, more especially when the employer has taken no measures for providing fresh water, and most of all when the measures for the prevention and elimination of dust are inapplicable or inadequate.

In dusty industries, the paralysing action exerted by alcohol on the vibratile cilia of the respiratory passages attenuates or suppresses their defensive action, thus favouring the entry of dust into the deepest recesses of the respiratory tract. Pneumonocnosis thus prepares the ground for phthisis.

Even apart from dust, the relation between alcoholism and tuberculosis is a very intimate one. Bertillon has shown by occupational statistics that the trades with the highest consumption of alcohol show the highest mortality for phthisis.

According to Imbert's well-known statistics, alcoholic subjects are met with most frequently in the following trades (proceeding from highest to lowest): vendors of alcoholic beverages, hotel keepers, pedlars, cooperers, day labourers, transport workers, carriers, cabmen, labourers, bakers, cooks, butchers, pork butchers, waiters, locksmiths, chauffeurs, mechanics, domestic servants, packers, printers, painters,
Among women the categories in which alcoholism is most prevalent are: hotel servants, hawkers, waitresses, domestic servants, cooks, hairdressers, con-
cierges, housemaids, charwomen, women without an occupation, seamstresses, milliners, artists in café-concerts, artists' models, hospital nurses.

More recent statistics prepared by Heilig show that in Germany day-
workers constitute 54 per cent. of the alcoholics; peasants 15 per cent.; em-
ployees, members of the liberal professions and business people 24 per cent.;
accountants, tailors, shopmen, shoemakers, ostlers, hotel keepers and waiters 19 per cent.

Occupations which begin at an early hour predispose to the matutinal "schnapps"; intertemperance during work is also frequent amongst those who have to make great muscular effort and are not kept under strict discipline (dockers, carters, quarrriers, builders, labourers, sailors).

Alcoholism is very widespread among: zinc smelters, either from the tradition that alcoholic liquors are an antidote to the zinc and other metallic toxic substances, or to counteract the action of heat, dust, fumes and fatigue; aviators (an accident has often followed on the morrow of excessive consumption of alcohol); miners (during their rest time), etc. In America, among soldiers, the rate has fallen from 35 per 1,000 in 1907 to 6.97 per 1,000 in 1920.

**STATISTICS**

So far as morbidity is concerned, statistics reveal the frequency of alcoholic psychosis—one of the gravest effects of alcoholic intoxication. In France, on 1 January 1907, of 71,547 cases of insanity 3,008 cases were exclusively the result of alcoholism; among 3,285 others, the alcoholic affection was complicated with mental degeneration or debility or a history of alcoholic parenage. In 3,639 insane persons suffering from different maladies, alcoholic intoxication was one of the determining causes. A total, therefore, of 9,932 cases (13 per cent.) can be ascribed more or less directly to alcoholism. This is in accordance with statistics of Mirnal, whose view is that 13.60 per cent. of the total inmates of asylums in France is made up of alcoholics.

In Italy, according to Amaldi, cases of alcoholic insanity (from the period 1909-1921) among asylum inmates are as follows: industrial class, 43 per cent.; agricultural and analogous classes, 33.6 per cent.; employed in commerce, 8.3 per cent.; liberal professions, 6.5 per cent.

If these figures be compared with those of the period 1903-1905, a slight diminution will be seen to have taken place among the industrial workers (43 per cent. as against 49.8 per cent.), an increase in agricultural labourers (33.6 per cent. as against 21 per cent.) and a notable diminution in the group of the liberal professions (in the middle and lower middle class population).

When mortality statistics, are examined in the professions where alcoholic excess is noticeable, their relative increase is striking. According to Jaquet, 1,000 adult males between 39 and 49 furnished at Paris an annual death rate of 36.1; whilst for 1,000 publicans at the same age the figure is 46.9 The figures for Switzerland are similar. As against 25.8, the general mortality rate per 1,000 adults, that for publicans is 42.59.

According to the English official statistics, phthisis accounts for the death of 67 clergymen and 105 doctors, as compared with 448 publicans and 607 barmen.

With a comparative mortality figure of 100 for alcoholism and diseases of the liver, that of dock labourers is 167 for the period 1900-1902, and 187 for that of 1910-1912.

From the Supplement to the 75th Annual Report of the Registrar-General for England and Wales (Part IV: Mortality of Men in Certain Occupations in the Three Years 1910, 1911, and 1912), it is at once easy to show that the comparative mortality figure for alcoholism has fallen from 43 to 23, that is, a drop of 47 per cent. The total number of deaths from alcoholism and diseases of the liver, which was 294 per million in 1900, is only 156 in 1910, and 84 in 1920. The death rate for alcoholism in the different social classes works out as follows:

<table>
<thead>
<tr>
<th>Group</th>
<th>Deaths from alcoholism in the groups having a comparative mortality figure of</th>
<th>Mortality percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>less than 600</td>
<td>600 to 600</td>
</tr>
<tr>
<td>Skilled and semi-skilled workers</td>
<td>7 (1.3)</td>
<td>10 (1.6)</td>
</tr>
<tr>
<td>Unskilled workers</td>
<td>7 (1.2)</td>
<td>—</td>
</tr>
<tr>
<td>Liberal professions</td>
<td>15 (9.8)</td>
<td>24 (3.7)</td>
</tr>
<tr>
<td>(officials and clerks)</td>
<td>16 (3.0)</td>
<td>20 (3.1)</td>
</tr>
<tr>
<td>Shopkeepers</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Brewers, publicans</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Note. — The figures in brackets indicate the ratio between the mortality from alcoholism in each group and the general mortality.

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This table shows that the mortality from alcoholism, expressed as a percentage of the general population, is pretty well constant.

Among skilled workers the mortality for all causes varies from 45% (gardeners) to 1,196% (potters) and it is apparent that mortality from alcoholism increases pari passu with the general mortality figure, except in the case of publicans and the like, where the percentage is higher. The relation between mortality from alcohol and the general mortality of industrial workers is constant, but is different when workers engaged in the sale of alcoholic liquors are in question, proving that alcohol has a direct influence on mortality.

Comparison between different groups alike in regard to environment and social status, but one of which is more or less addicted to alcohol enables account to be taken of the relation between the general mortality figure and consumption of alcohol. Thus, on the one side, there are the inn and hotel keepers and wine, beer and spirit dealers, and on the other the general group of shopkeepers (drapers, grocers, butchers, stationers, ironmongers, retail tobacco shops, chemists, etc.).

| MEAN ANNUAL DEATH RATE PER THOUSAND LIVING, 1910-1912 |
|---------------------------------|----------------|----------------|----------------|----------------|----------------|
| Age                        | Brewers | Inn, hotel keepers | Inn, hotel servants | Waiters | All males |
| 15-20 years                 | 3.54    | 2.19              | 2.08              | 2.49    | 2.88       |
| 20-25 years                 | 3.38    | 2.47              | 3.55              | 3.18    | 3.72       |
| 25-35 years                 | 6.75    | 2.72              | 2.85              | 5.77    | 4.89       |
| 35-45 years                 | 5.95    | 7.26              | 7.82              | 11.81   | 7.99       |
| 45-55 years                 | 2.15    | 2.54              | 3.06              | 21.58   | 16.62      |
| 55-65 years                 | 36.06   | 41.32             | 33.54             | 35.36   | 29.69      |
| Over 65 years               | 97.00   | 114.21            | 73.43             | 92.95   | 83.33      |

<table>
<thead>
<tr>
<th>DEATHS IN STANDARD POPULATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cause of death</td>
</tr>
<tr>
<td>All causes of death</td>
</tr>
<tr>
<td>Phthisis</td>
</tr>
<tr>
<td>Diseases of the respiratory system</td>
</tr>
<tr>
<td>Diseases of the circulatory system</td>
</tr>
<tr>
<td>Diseases of the nervous system</td>
</tr>
<tr>
<td>Diseases of the liver</td>
</tr>
<tr>
<td>Alcoholism</td>
</tr>
</tbody>
</table>

The comparison is even more apt if the following figures are taken:

<table>
<thead>
<tr>
<th>Mean annual death rate per 1,000 living</th>
<th>Deaths in standard population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profession</td>
<td>20-25 years</td>
</tr>
<tr>
<td>Brewers</td>
<td>3.28</td>
</tr>
<tr>
<td>Inn, hotel servants</td>
<td>3.55</td>
</tr>
<tr>
<td>Inn, hotel keepers</td>
<td>2.47</td>
</tr>
<tr>
<td>All occupied and retired males</td>
<td>3.52</td>
</tr>
</tbody>
</table>
In the Netherlands, the same figures for the same professions can be shown (no dates given):

<table>
<thead>
<tr>
<th>Professions</th>
<th>Comparative Mortality figure from alcohol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doctors</td>
<td>93</td>
</tr>
<tr>
<td>Hospital personnel</td>
<td>106</td>
</tr>
<tr>
<td>All professions</td>
<td>109</td>
</tr>
</tbody>
</table>

Vernon's study of the figures shows that the changes noted in the general mortality of industrial workers must be attributed to some cause other than alcohol, such as unhealthy conditions of work which diminish the standard of general health and render the workers more sensitive to the action of alcohol. Attention has been already frequently called to this point. On the other hand, lessened vitality renders the workers more inclined to seek enjoyment in alcohol.

Really, the general mortality figure is sufficiently low in the open air professions (railway workers, shipbuilders, etc.) or under roofs (sawing, carriage making), and increases the more the professions are carried on in interiors (carpenters, boiler makers, printers) and becomes most marked in dusty industries or at high temperatures (iron, steel, and glass works and in hot mines). For unskilled workers the figures for Great Britain on this point are as follows:

<table>
<thead>
<tr>
<th>Profession</th>
<th>Comparative Mortality figure from alcohol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick and tile makers</td>
<td>567</td>
</tr>
<tr>
<td>Road labourers</td>
<td>621</td>
</tr>
<tr>
<td>Coal porters</td>
<td>12</td>
</tr>
<tr>
<td>Carriers</td>
<td>17</td>
</tr>
<tr>
<td>Coach, cab and omnibus grooms</td>
<td>500-957</td>
</tr>
<tr>
<td>Day labourers</td>
<td>23</td>
</tr>
<tr>
<td>Dock labourers</td>
<td>1,102-1,507</td>
</tr>
<tr>
<td>Messengers, porters, etc.</td>
<td>22-35</td>
</tr>
<tr>
<td>Coattailors</td>
<td>8</td>
</tr>
</tbody>
</table>

The middle and upper classes comprise principally the liberal professions and office workers. How their general mortality is lowered while that for alcoholism increases is proved by the following British statistics:

<table>
<thead>
<tr>
<th>Profession</th>
<th>Comparative Mortality figure from alcohol</th>
</tr>
</thead>
<tbody>
<tr>
<td>School masters</td>
<td>12</td>
</tr>
<tr>
<td>Bank clerks</td>
<td>17</td>
</tr>
<tr>
<td>Civil servants</td>
<td>17</td>
</tr>
<tr>
<td>Office attendants</td>
<td>4</td>
</tr>
<tr>
<td>Clergy</td>
<td>17</td>
</tr>
<tr>
<td>Railway personnel</td>
<td>16</td>
</tr>
<tr>
<td>Architects</td>
<td>20</td>
</tr>
<tr>
<td>Doctors</td>
<td>27</td>
</tr>
<tr>
<td>Lawyers</td>
<td>28</td>
</tr>
<tr>
<td>Artists</td>
<td>31</td>
</tr>
<tr>
<td>Insurance agents</td>
<td>8</td>
</tr>
<tr>
<td>Solicitors' clerks</td>
<td>24</td>
</tr>
<tr>
<td>Commercial travellers</td>
<td>25</td>
</tr>
<tr>
<td>Chemists and druggists</td>
<td>35</td>
</tr>
<tr>
<td>Commercial clerks</td>
<td>20</td>
</tr>
</tbody>
</table>

According to this table, doctors, lawyers and artists has a low general mortality, but a rather high one from alcoholism (higher than that of industrial workers), which can be explained by the nature of the drink consumed.

The diagnosis of acute or chronic alcoholism raises no particular importance. It should be remembered, however, that the clinical aspect of alcoholism resembles that produced by certain industrial poisons (petroleum, benzene, carbon bisulphide, carbon monoxide, etc.).

**Prophylaxis**

Without desiring to repeat all that can be said and prescribed in regard to personal and social prophylaxis against alcoholism, nor again all that comes within the domain of social prophylaxis in regard to this form of poisoning, it is necessary to bear in mind certain points relative to prevention of excessive drinking in industry.

At the outset, workers whose constitution has been injured by alcoholism must be prohibited from taking up certain trades. Thus, for example, alcoholic subjects who are found to be suffering from lung or kidney disease ought to be kept out of explosives factories. Similar examples could be multiplied indefinitely.

On the other hand, reduction in the amount of alcoholism can only be expected by improvement in the hygienic and social conditions of the industrial environment. All labourers, agricultural or otherwise, who drink are under the impression that they cannot perform their daily task without stimulants. This would appear to be really true in some measure of certain jobs in the factory and on the land. Improvement in the conditions of work, a veritable revolution in the way in which work is organized, are indispensable for reducing alcoholism among the working classes and agricultural labourers.

**Legislation**

Details as to legislation on this subject cannot be given—the more so as it extends over a much wider field than industrial hygiene alone. In this connection legislation makes provision for special measures such as: prohibition of the introduction of alcoholic beverages into workrooms especially where poisonous products are handled, or in works coming under the Factory Act; prohibition or the payment of wages to workmen in kind; or part payment in kind (wine, beer, etc.); or allowing workers (as in breweries, etc.) free access to drink. Alcoholic drinks should not be granted certificates of fitness when required in certain occupations...
(e.g. compressed air work, chauffeurs, etc.) or should not be accepted for other kinds of work, e.g. manufacture of white lead, lead oxides, etc.

**Prof. G. Allevi**
(Milan).

### Aldehydes

Under the name of aldehydes are understood the organic substances containing the atomic group H — C=O from the oxidation of alcohols and constituting the transition products between these and the corresponding acids.

The oxidation product of ethyl alcohol known under the name of aldehyde is only acetic aldehyde or acetaldehyde (see that article).

Amongst other aldehydes there should be recalled anisyl aldehyde, obtained (see that article) by direct oxidation.

It is of interest to note that aldehyde can be transformed into alcohol by hydrogenisation on nickel at 140° C. It is prepared industrially by hydration of acetylene in a solution of mercuric bichromate of potassium or soda and sulphuric acid. The mercury salt is recovered. When all the mercury salt has combined, the complex is decomposed by boiling with dilute sulphuric acid. The mercury salt is recovered and the volatile aldehyde which is given off is sent into a hydrogenisation apparatus in which the catalyst is deposited. The fumes of aldehydes not transformed are condensed at the exit by powerful refrigerating agents.

"While the manufacture of alcohol starting with aldehyde reached a high degree during the war, it is at present of slight importance; but the inverse reaction may now become very important, for ordinary aldehyde is used in the preparation of acetic acid (see that article) by direct oxidation.

Ordinary alcohol is easily transformed into aldehyde by simple dehydrogenation (CH₃CH₂OH=H₂+CH₂COH), easily effected by contact with light copper at 300° C.

The oxidation of ordinary aldehyde in acetic acid is at present an industrial process. It is effected by air or oxygen in the presence of oxide catalysts (oxides of vanadium, uranium, cerium, etc.) and certain acetates (manganese, cerium, etc.). The aldehyde is first introduced into the cast-iron apparatus (oxidisers) and then the oxide catalyst or the salt. The reaction is set in motion by heating slightly.

For pathology, hygiene, etc., see article "Acetic Aldehyde".

***

### Alizarin

French: Alizarine. — German: Alizarin. —
Italian and Spanish: Alizarina.

**Chemical Properties**

Alizarin is the colouring matter of madder, from which at one time it was exclusively obtained, but synthetic alizarin is now obtained from anthraquinone.

Chemically pure alizarin [formula: C₆H₄(CO)₂C₆H₂(OH)₂] crystallises in the form of orange needles: melting at 290° C. is insoluble in water, soluble in boiling alcohol, in ether, in mineral acids, etc.

Commercial alizarin is usually in the form of an ochre yellow paste containing 30-40 per cent. of dry colouring material, but it may however be powdered or in small pieces. With a mordant colouring agent it dyes textiles (cotton, silk and wool) red with alumina mordants, orange with tin mordants, crimson to chestnut with chrome mordants, and violet with iron mordants.

**Alizarin purple** is a reddish brown paste almost insoluble in water, soluble in alkalis, in fuchsin red and in sulphuric acid.

**Bordeau or China alizarin**, used for dying cotton with alumina, chrome, and iron mordants, is another well-known variety. Many varieties varying slightly in preparation and in the degree of purity are known in commerce.

**Method of Preparation**

Alizarin is prepared synthetically in great quantity and is got from anthracene, first transformed into anthraquinone by treatment with bichromate of potassium or soda and dilute sulphuric acid in presence of heat. The raw anthraquinone is then purified with fuming sulphuric acid giving monosulphonic anthraquinone, which in turn gives alizarin by repeated heating with concentrated caustic soda (preferably with the addition of a little nitrate or chloride of soda). Production is effected in cast-iron kettles provided with stirrers. Alizarin purple is obtained by oxidising alizarin with peroxide of manganese and sulphuric acid and Bordeaux or China alizarin by oxidation with fuming sulphuric acid.
**USE IN INDUSTRY**

Alizarin is used as a mordant dye for dyeing cotton, silk and wool. These dyes will not by themselves combine with the fibre, but combine with metallic oxides to form "lakes." The material or hanks of yarn are impregnated with the dye, a process known as "padding" and the mordant is applied by passing the hanks through vats or if in the piece through troughs known as "jigs". The categories of workers exposed to the effects of alizarin are: workers handling the product in process of production; dye-workers coming in contact with alizarin dyes, chiefly "padders" and "jiggers", and bobbin winders in cotton mills engaged on the process known as "halching" where yarns dyed with alizarin are manipulated. These workers wind the yarns and use them to tie up hanks taken from the winding frames, using the index finger to break the three or four-fold tie.

**SYMPTOMS**

Skin affections of an eczematous type have been found amongst workers handling alizarin. One authority, in a statistical table of 84 cases of eczema occurring in a synthetic dye-stuffs factory, shows 13 as having occurred amongst alizarin workers. Cotton mill workers engaged in halching were found to suffer from a mild dermatitis, occasionally with blistering of the skin on the fingers, chiefly the index finger. If the workers' hands were chapped, cracked or sore, they became inflamed and festered. Grandhomme considers the danger from alizarin to be comparatively slight. Workers engaged in the preparation of the product and also in dyeing are likewise exposed to chrome poisoning (see article "Chrome"). The possibility of epitheliotomatous ulceration due to alizarin among the above-mentioned categories of workers must also be taken into account. ***

**Alkalies**


The manufacture and use of alkalies (caustic soda or potash, ammonia, etc.) and their more or less concentrated solutions (lyes) are a very common cause of lesions of an occupational character.

In the soap and grease industry particularly and in the chemical industries the use of alkalies is common; in dilute solutions they are used in the textile industries (e.g. in wool washing before dyeing, in mercerising cotton, etc.), in engineering and the metal industry, in the rubber trade, in bleaching, in restaurants (dish washers), and even in the home for washing table ware, etc., in industry generally for washing the hands when soiled by grease, oils, colours, etc.

Alkalies are caustic both in the solid state or in concentrated solutions. Their local action is generally more potent and more extensive than that of acids. They do not, it is true, coagulate the proteid substance of the tissues, but by dissolving the layer of natural grease which protects the skin they cause this to dry, harden and crack, and so render it more susceptible to the action of micro-organisms than do other physical and chemical agents.

The lesion caused by alkalies is typically weeping, humid, nummular. The dermatitis takes on the most varied forms, but is generally an eczema.

The nails undergo a more or less profound degeneration; they become fragile and fall off. This action is more marked if the alkalies are in dilute solution. Fragments of caustic dust or droplets of liquid alkali exert very injurious action on the eyes. The ocular lesions, especially of the conjunctiva and cornea, are, however, less dangerous as a rule than those set up by acids. Of the alkalies, ammonia (see that article) penetrates most deeply into the tissues of the eye.

**STATISTICS**

As in the case of acids, it is possible to complete the data concerning the pathology of workers employed in the chemical industries by those dealing with the departments of alkali manufacture. These statistics, prepared by Leymann, treat of them, however, for different periods, as is seen in the following table:

<table>
<thead>
<tr>
<th>Number of workers (annual average)</th>
<th>Potash</th>
<th>Soda</th>
<th>Soda of soda</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diseases of the nervous system</td>
<td>45</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>Diseases of the circulatory system</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Diseases of the respiratory system</td>
<td>344</td>
<td>51</td>
<td>916</td>
</tr>
<tr>
<td>Diseases of the digestive system</td>
<td>292</td>
<td>83</td>
<td>949</td>
</tr>
<tr>
<td>Diseases of the urinary system</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Infectious disease</td>
<td>117</td>
<td>45</td>
<td>72</td>
</tr>
<tr>
<td>Intoxications</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Burns</td>
<td>40</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Other lesions</td>
<td>218</td>
<td>80</td>
<td>930</td>
</tr>
<tr>
<td>Diseases of locomotory organs</td>
<td>215</td>
<td>56</td>
<td>201</td>
</tr>
<tr>
<td>Diseases of the skin</td>
<td>157</td>
<td>71</td>
<td>139</td>
</tr>
<tr>
<td>Diseases of the eyes and ears</td>
<td>70</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Diseases of the generative organs</td>
<td>13</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

1,468 | 511 | 1,283
Burns from alkalies numbered 78 in 1881, 88 in 1890 and 28 in 1900.

Ocular lesions caused by alkalies numbered 50 for the period 1881-1890, 36 for the period 1890 to 1900, and 18 for the period 1900 to 1904.

(See also the article "Chemical Industries ")

HYGIENE

Generally the same precautionary measures are necessary as have been described in the case of acids, especially in regard to transferring, transport, filling of bottles, etc.; arrangements as to manufacture and manipulation of alkalies are laid down in the articles "Ammonia" and "Caustic Soda Lye", etc. For the treatment of effluents see article "Waste Water".

The most important point to attend to in the treatment of burns is to dilute the corrosive substance either by water or by slight acid solutions (acetic acid or even vinegar). Treatment should be as prompt as possible while waiting for the surgeon. Overall, gloves, goggles, etc., should be worn as described in the article on acids. Ointment (e.g. lanoline) can usefully be rubbed on the hands and forearms.

LEGISLATION

Young persons of less than 16 years of age are prohibited from work in the manufacture or use in dangerous quantity of caustic lyes in the United States in the States of Alabama, California, Kentucky, Maryland, New Jersey, Ohio, Oklahoma, Wisconsin, and under 15 years of age in the State of Delaware (preparation of chemical lyes); boys under 16 years and girls under 18 in Greece in alkali manufacture; boys under 16 years and females under 21 in Spain in the manufacture of caustic alkalies (see also the articles "Ammonia", "Caustic Soda Lye", etc.). The regulations are analogous to those set out in the article "Acids" and are to be found in the same regulations.

Thus, for example, the British regulations of 11 July 1922 require in works or parts thereof in which:

1. Caustic pots are used;
2. Chlorate or bleaching powder is manufactured;
3. (a) Gas tar or coal tar is distilled or is used in any process of chemical manufacture;
   (b) A nitro or amido process is carried on;
   (c) A chrome process is carried on;
4. Crude shale oil is refined or processes incidental thereto are carried on; or
5. Nitrile acid is used in the manufacture of nitro compounds:

Every caustic pot shall be of such construction that there shall be no foothold on the top or sides of the brickwork or flues; and, the edge of every such pot constructed, rebuilt or replaced after these regulations come into force shall be at least 3 feet in height above the adjoining ground or platform.

Lastly the Russian regulations of 10 April 1922 deal with the manufacture of caustic bases, and of sulphate of soda, etc.

Ulceration of the skin set up by caustic liquids is treated as an accident for the purpose of compensation in the British Workmen's Compensation Act and in New South Wales; the eczematous conditions in Western Australia; conjunctivitis in Japan. Lesions set up by lyes are also subject to compensation in Japan, Finland, and Switzerland. 


Allyl Alcohol


Allyl alcohol is a liquid with a pungent smell, the formula of which is CH₃=CH.CH₂OH. It is very soluble in water, boils at 98° C., and the specific gravity is 0.8573 at 15°. It is obtained in small quantities from dry distillation of wood. Industrially it is obtained by heating glycerine with oxalic and formic acid. Glycerofomorlic ether is formed which decomposes between 200° and 260° C., giving allyl alcohol. It is separated by distillation. Allyl alcohol is used in the preparation of bromide and iodide of allyl, allyl ethers, and cinnamon and salicylic acids.

One of the most important derivatives of allyl alcohol is essence of mustard formed chiefly of allyl cyanate. It can be extracted from mustard seeds, but is often also obtained by distillation of allyl iodide with sulphocyanate of potassium.

Medical literature records only cases of severe irritation of the mucous membrane with lachrymation, conjunctivitis, increased nasal secretion, etc., amongst workers exposed to the fumes of allyl alcohol in course of its manufacture.

For further details, see article "Ethyl Alcohol".


Alum


Ordinary alum or potassium alum (for the other varieties, chrome, iron, etc., see articles "Chrome", "Iron and Steel Industry", etc.) is a double sulphate of aluminium and potassium \([\text{SO}_4, \text{Al}, \text{SO}_3, \text{K}_2+24\text{H}_2\text{O}]\) in the form of a colourless transparent crystallisable salt soluble in 10 parts of cold water and 5 parts of boiling water. Its density is 1.735; it melts at 90° C. In an anhydrous state it forms calcined alum, white, friable and slightly caustic. The active principle of alum is aluminium sulphate, with the result that the latter, or sodium aluminate, is becoming more and more frequently substituted for it.

Alum is recovered from certain kinds of earth containing, at the same time, aluminium sulphate and potassium sulphate (natural alum, alumite) or the elements which go to their formation (aluminous earth, aluminous schists). Natural alum is chiefly found in volcanic regions (Italy: Neapolitan Campagna, Stromboli; Greece: Milo; Switzerland: the Canton of Uri; United States: Tennessee).

Alum is obtained, from the natural product, by dissolving in water and crystallising the solution, or from alumite by roasting the mineral, treating with hot sulphuric acid, adding potassium sulphate and crystallising, or again from aluminous earth and aluminous schists by oxidising the mineral in presence of air, lixiviation and crystallisation of the solutions after addition of potassium sulphate, or finally from alumminium sulphate (the solutions of potassium sulphate and aluminium sulphate being mixed in equimolecular proportions).

Alum is used in the textile industry (dyeing and printing as a mordant — especially anhydrous alum); in the leather and hide industry (tanning, currying, tawing, morocco dressing, and for leather dyeing); in the paper industry (for gluing paper); in the colour and varnish industry (manufacture of lakes). It is further employed for fireproofing wood and cloth and for clarifying water, etc.

According to White, immersion of the hands in a solution of alum may set up cutaneous irritation, a crust of aluminium oxide with a corrosive action forming on the skin, which becomes hardened, tanned, and cracked. Bauer states that alum may cause ulceration of the toes and particularly of the ungual groove of the large toe.

During the operation of roasting the alumite, gas containing about 3 per cent. of sulphurous anhydride is given off. The kilns used must therefore be airtight and the sulphurous gases drawn off by an exhaust apparatus and thereafter absorbed, preferably by means of chambers or towers and the application of water with soda or potassium in solution. On the other hand, the material requires to be broken up prior to roasting. This operation should be effected in closed mixers (ball mills or disintegrators), and any dust which may escape should be withdrawn by local exhaust and subsequently filtered.

Ordinary measures of hygiene are called for in relation to the workshops (floors, walls, etc.) and also removal of fumes and acid vapour, installation of ventilation treliss and decantation and purification of all waste water before leaving the factory.

Aluminium


Properties

Aluminium (symbol: Al) is not found as a metal in a pure state in nature, but nevertheless it is extremely widespread in various combinations. It is even the commonest metal in the soil, and, with the exception of oxygen and silicon, the most widespread substance in the world. One finds it in numerous mineral matters — clays, granites, porphyries, micas, etc. — and in precious stones such as rubies, sapphires, corundums, etc.

Aluminium is generally obtained from bauxite (hydrated aluminium \((\text{Al}_2\text{O}_3,2\text{H}_2\text{O})\), the strata of which are found in the South of France, Calabria, Hungary, etc.) and cryolite (the double fluoride of aluminium and sodium \((\text{Al}_2\text{F}_3,3\text{Na}_2\text{F})\) found in Greenland, Iceland, Alaska, Denmark, etc.).

In a pure state aluminium is a bright, silverly bluish, white metal. In structure it is slightly fibrous; its consistency is not very great, but if, in this respect, it is weaker than copper and its principal alloys, it is, on the contrary, harder than tin or zinc.

The atomic weight is 27.1; its specific gravity varies with its state, corresponding to 2.64 when in the molten state and
268° C. in laminated form, and 270° when drawn. Aluminium melts between 625° and 655° C. and boils at 1,800° C. Its heat conductivity is 0.345 at 0° and its co-efficient of expansion 0.000231.

Further, it is interesting to note that its specific heat is very high (0.235 at 100 degrees) and it is the same in regard to its melting point, so that therefore, in comparison with other metals, it calls for a great quantity of heat to melt it.

Aluminium is very ductile and malleable; in this respect it comes next to gold. It stands exposure to air well notwithstanding its affinity for oxygen. Exposed surfaces become covered with a layer of oxide, hardly perceptible, however, which does not detract from the pleasant look of the metal, and serves as a protection against further attacks.

While aluminium offers very strong resistance to certain substances, it is on the contrary attacked violently by others. It is highly resistant to acetic acid, formaldehyde, oxygenated water, fats and fatty acids. This makes it very serviceable for domestic use. It also resists very well the action of water if free from foreign metals.

Aluminium vessels strongly attacked by certain waters may be rendered refractory by a "re-baking" at 250° C., especially if this is repeated several times, in an oxidising atmosphere. This operation results in coating the surface with a layer of oxide sufficient to protect the metal against attack from dangerous waters.

Recently (1924) Hatfield has shown, in reference to the presence of soluble aluminium sulphate, that the limit of insolvability for aluminium is between 5.7 and 7.3 (hydrogen ion concentration). In waters clarified by aluminium sulphate of which the hydrogen ion concentration is below or above these figures, soluble aluminium might be found.

The sensitiveness of aluminium to mercury is so great that the slightest trace of this substance in the water gives it a great power of attack.

Aluminium is a reducing agent acting energetically on the oxides and numerous metals. It is dissolved in hydrochloric and sulphuric acids giving off hydrogen; on the other hand it is not acted on by nitric acid. Aluminium is rapidly dissolved by soda and potash with evolution of hydrogen. It is attacked by the halogen group.

Aluminium readily forms an amalgam with mercury which is obtained directly by placing mercury in contact with aluminium in the powder or by heating aluminium with a 1½ per cent. solution of sublimate. In the presence of water this amalgam decomposes it rapidly and at the oven temperature, forming synthetic ruby, hydrate (AlO.H₂) and giving off hydrogen.

Compounds of aluminium are numerous — e.g. the chloride [Al Cl (3)], prepared by passing a current of hydrochloric acid gas over aluminium turnings, is a substance used in organic syntheses; oxide of aluminium (see above), a white powder, insoluble in water, melting at 2,050° C. and used in the preparation of refractory materials and the manufacture of artificial precious stones; synthetic ruby, obtained by melting, with the oxyhydrogen blowpipe, aluminium mixed with chrome oxide; ultramarine, a very beautiful colouring matter, the composition of which is not known, but which is obtained by heating, in the absence of air, either a finely powdered mixture of kaolin, sulphur and soda, or a mixture of kaolin, Glauber's salt, sulphur and carbon. During the reaction a large quantity of sulphurous anhydride is given off.

INDUSTRIAL PROCESSES

Aluminium has only been manufactured on the industrial scale recently because of the difficulties in its production. Large sources in electrical power were necessary before an abundant cheap production was obtained. The primitive methods are now done away with and constant improvements make production easier and easier.

The methods actually in vogue are based on the principle of according to electrolysis a solution of alumina (oxide of aluminium) in a bath of cryolite melted at a high temperature. (carbon electrodes are used). In theory only the alumina should be decomposed; the metal passing to the cathode is deposited on the bottom of the furnace and the oxygen set at liberty with the carbon of the anode (which is rapidly consumed) becomes oxidised, forming carbonic oxide, which, on burning, becomes converted into carbon dioxide.

From the point of view of the output from these processes, Ullmann states that it should be possible to produce 0.337 grm. of aluminium per ampere hour with 3 volts, which corresponds to 42.1 grm. per B.T.U. and 365.7 kg. per kw. A normal bath would allow of a theoretical utilisation of the current of 90-95 per cent. But many causes of loss lower the effective utilisation of 60-65 per cent. corresponding to a yield of 210-275 grm. of aluminium per kw., which theoretically is equivalent to a production of 1 kg. of aluminium from the use of 1,889 grm. of alumina and 333.5 of carbon at the anode (or 696.7 kg. of carbon in CO₂). But in practice higher quantities are required.

The metal thus produced contains 98-99 per cent. of aluminium (it may reach 99.5 per cent.). The principal impurities are silicon and iron — sometimes copper. Sodium, as has already been said, is the substance which is most injurious to the metal.
The cryolite which serves for the composition of the electrolytic bath is to-day often obtained artificially, or its place is taken by other fluorides; the production of these substitutes deserves attention from the point of view of hygiene because of the troubles and danger they may bring — the danger being the same as those common to the chemical industries and particularly manipulation of fluorine and its acids. Further, it is important that these products should be as free as possible from silicic acid.

But by the decomposition of the alumina oxide in the course of the process of electrolysis the bath reaches a stage when there is not enough alumina; the cryolite can then itself undergo electrolytic action (which in practice is frequently the case), and so it comes about that, as the result of the decomposition of the fluorides of aluminium and sodium, gases of fluorine are given off at the anode and sodium is deposited at the cathode. Alumina will not tolerate the presence of sodium even in traces, because the quality of the metal so obtained is faulty. It is necessary, therefore, constantly to feed the bath with alumina to maintain the necessary proportion of cryolite. The success or otherwise of the operation depends to a large extent on how the bath is constituted and maintained, and equally the experience gained in each factory permits the use of baths of differing composition with a view to better production.

The temperature of the baths is not always the same, but as aluminium commences to melt at about 650° C., their temperature must necessarily be higher than this; it can vary between a minimum of 700 and 1,000° C.; in practice it varies from 800° to 900° C.

Alumina to be used in making aluminium must be as pure as possible. It is obtained from bauxite, an aluminium hydrate poor in water, which, submitted to a preliminary treatment, is converted into pure alumina, after elimination of iron and silicon. The processes of purification resemble each other generally, and consist in the treatment of bauxite with caustic soda. The alumina is converted into soluble aluminate; the iron and the silicon are eliminated by filtration. Carbon dioxide is then passed through the solution of aluminate, which precipitates the pure hydrated aluminium. The solution of aluminate also can be mixed with a small quantity of hydrated aluminium; the dissolved alumina is carried down by precipitation and the alkali is liberated (Bayer). Pure aluminium is also prepared by utilising solutions of aluminate of soda remaining over from the manufacture of ammonia by the process of Serpek (see article "Ammonia").

**Uses**

In consequence of the fall in the price of aluminium, its use for culinary utensils has recently greatly increased; it is gradually but constantly replacing copper, enamelled iron and earthenware. The vessels are either cast or manufactured out of sheets of metal or finally hammered. Aluminium can even be used for chemical and industrial purposes (special cast vessels, etc.).

The waste from these manufactures is used, after being reduced to powder, in the production of bronze powders (see later).

Aluminium reduced to a fine powder, and suspended in varnishes or drying oils, serves for ornamental painting, or for a protective coating (e.g. against rust). The very fine powder is used in lithographing and also in the production of explosives (ammonal).

Aluminium further plays an important rôle in metallurgy in the casting of irons and silicas, or it is added in small proportions (0.02-0.05 per cent.) to reduce the dissolved oxide of iron. It serves also in the making of alloys such as aluminium, bronzes, and special light alloys for aeronautical work.

The aluminium bronzes are very numerous; there are two important groups according as the proportion of copper or aluminium preponderates. The bronzes predominating in copper contain 5 to 10 per cent. of aluminium and those predominating in aluminium have only 3 to 6 per cent. of copper.

Mention should be made further of the bronzes properly so called (tin, copper) which contain aluminium also and are special bronzes in which aluminium is present only in very small quantities (less than 1 per cent.). In such an alloy the aluminium only plays a deoxidising rôle. Larger quantities would increase the brittleness of the mass.

The aluminium bronzes are alloys of copper and zinc in which the aluminium enters in variable quantity but always slight (from 0.3 to 4 per cent.). The use of aluminium for electric cables instead of copper is extremely important, because even though there is required for an equivalent conductive power greater thickness of aluminium.
wire than of copper wire there is an advantage in using aluminium instead of copper as it weighs less and consequently effects a considerable economy in the manufacture of the supports.

Aluminium is also used in the preparation of metals such as chrome, tungsten, molybdenum, for the reduction of their oxides.

Alumino therm. A metal or its alloy having reducing properties acts upon a metal compound in such a way that, lighted at its end, it continues to burn of itself with development of high temperatures. The metal reduced, after oxidation of its active elements, then separates, forming a solid mass and a liquid residue. The phenomenon has this peculiarity, that the operation goes on without the mixture receiving any additional heat from outside necessary for the reaction.

Aluminium is the most important of the reducing agents; in practice the action is used especially in the case of oxides, more rarely on sulphides, chlorides, and nitrogen salts.

The name "thermite" is given to a mixture of aluminium and iron oxide, which, on being ignited by a small quantity of an inflammable mixture, gives rise to a special reaction; at the end of the operation in the still hot crucible a molten mass is formed, consisting of a layer of ashes and a metallic block. Thermite is used to solder rails end to end; it was used during the war to make incendiary pastilles.

TOXICITY — SOURCES OF DANGER

Aluminium is not, properly speaking, a toxic metal, and its presence in animal tissues, at any rate in appreciable quantities, has not been found. Very minute proportions have been traced in the intestines coming from food.

Aluminium compounds are only slightly toxic and fatal poisoning by them is quite exceptional.

From the point of view of industrial hygiene any ill-effects due to aluminium have been occasioned in the course of its manufacture: hydrofluoric acid vapour (see article "Hydrofluoric Acid") and carbon monoxide; accidental burns from spurtting of the molten metal; conjunctivitis set up by the bright and very long flames produced on the combustion of the gas; dangers of fire and explosion; and risk of electrocution.

The furnaces call for constant supervision: a single workman can watch several at the same time, but his vigilance must be directed to different points and particularly to the feeding of the bath.

Apart from the dangers incidental to manipulation, sometimes complicated, of objects at high temperature, particularly in a molten state, and danger of electric shock, there is intense evolution of toxic gases (fluorine, carbon monoxide).

The carbon monoxide is mostly burnt as it is formed, and seeing that plenty of oxygen is present, this risk in normal manufacture is slight.

It is not so, however, with the fluorine given off in considerable quantity, and this gas should be recovered and fixed in such a way as to be rendered inoffensive. To eliminate the fluorine which becomes immediately converted into hydrofluoric acid (and also into hydrofluosilicic acid, due to the presence of silicon from the carbon electrodes) there has been suggested the installation of hoods placed directly over each furnace and leading to a collecting chamber where the gases would come into contact with the fixing agent. This arrangement is not provided in all plants. It does not ensure elimination of all the fluorine, because it is often necessary to raise the hoods to see to the furnace.

In other factories the gases produced during electrolysis are allowed to escape freely into the furnace room, and, as a result of the high temperature on leaving the furnaces, they ascend rapidly and escape to the outer air through outlets specially arranged above. In other factories an attempt is made to fix them by making them pass through sprays of water placed all round outside the building. These procedures do not suffice to hinder the action of the toxic gases on the vegetation, and indirectly on the cattle near by.

In work with aluminium consideration has to be given to different manipulations. The work of the metal itself comprises casting, moulding, forging, rolling, stamping, compressing, assembling, soldering, finishing, polishing, etc., and, lastly, granulating and pulverising, in addition to the different treatment meted out to the powders according to their needs. Making aluminium bronze presents very serious risks. In the course of the different operations—especially of polishing—big explosions often occur, the cause of which is very obscure. Sometimes obviously they are dust explosions; but at others, in the presence of slight moisture, hydrogen gas is formed,
which, with the air present in the apparatus, forms an explosive gas on application of a light.

HYGIENE

Exploitation of aluminium preparations should be subject to special regulations; the machines should be placed in rooms set apart for the purpose and started and stopped from the outside.

The works should be situated away from human habitation, as well as from cultivated and pasture land (Cristiani).

The buildings should be of fireproof materials with impermeable flooring, etc.; electrodes of the furnaces should be controlled from a distance; decontamination and neutralisation of the residual waters should be carried out; the workers should have coloured goggles placed at their disposal; risk of electrocution and neutralisation of the residual materials, etc., should be prevented; apparatus for capturing dust, effective exhaust and ventilation, etc., should be provided (see articles "Fluorine" and "Hydrofluoric Acid").

LEGISLATION

Up to the present time, no regulations specially affecting aluminium factories have been made, although these may be classed under the heading of chemical or electro-chemical industries. Factories in which compounds of aluminium are manufactured come under the Chemical Regulations, 1922 (No. 731), in Great Britain. Special Rules for preventing accidents in the preparation of aluminium bronze powders were issued in Germany (1 July 1925).

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Prof. H. Cristiani (Geneva).

Amber

French: Ambre. — German: Bernstein. —
Italian: Ambra. — Spanish: Succino.

Amber is a fossilised resin, from the coniferous trees of the tertiary period, which has become solidified, crystallised and transformed in the earth. It is a hard, brittle body. Its density is 1.10 and it has an agreeable odour (some experts say it is odourless). It is generally yellow and translucent, but at times brownish-yellow or honey-coloured, yellowish white, hyacinth-red or black ("Iceland jet"). Pieces of a beautiful green shade are also found, but they are rare. Real amber melts between 250 and 300° C. and burns with a smoky flame. It is insoluble in water, slightly soluble in alcohol and ether. Its best dissolvent is chloroform. Distilled dry at 400° C. it decomposes into succinic acid and an oil and leaves a resinous residue known as colophany (rosin) used in the preparation of varnish. Amber can be cut and pared, but can neither be welded nor glued together again. It can be worked on a lathe like ivory or bone.

The principal deposits lie along the Prussian coast (Koenigsberg), and along the Courland, Livonian and Finnish coasts, in the Baltic Sea, on the west coast of Jutland, in the North Sea, in Siberia and in the Ural Mountains. Small quantities are found on the coasts of Madagascar and Sicily and in certain countries of Asia and the American continent. In France amber is chiefly extracted from the River Gard, where it is found mixed with lignite.

It is gathered on the banks or shore where nodules ("sprock"), surrounded with clay and algae, are thrown up by the waves or taken from the water in nets. It is subsequently extracted by excavation, sometimes in the open, sometimes from amber strata known as "blue earth", located at the level of the ground, and sometimes as far as fifteen metres below sea level.

At Koenigsberg amber is worked as a home industry by women. The waste is sent to factories where it serves in the manufacture of varnish
If OH is substituted twice for H, diphenol posed to the risk of poisoning, fire and taken into account as possible sources of danger. In the manufacture of the latter, the waste particles are caused to distend by the application of carbon disulphide, ether, benzol or petroleum spirit; they are then placed in a mould where they are subjected to strong pressure at a temperature of 300° C. The mass is then removed from the moulds and dried in the open air.

Artificial amber is produced from copal resin mixed with a little colophany (rosin). Imitation amber can also be made from celluloid, to the composition of which resin solutions (copal or gum lac) have been added. Amber is used for the manufacture of pipe stems, cigar and cigarette holders, jewels, heads of sticks, etc.

Sachs notes serious cases of dermatitis amongst women engaged on the manufacture of artificial amber ("bakelite"). Hot fumes of carbolic acid, formaldehyde and hydrochloric acid were given off during the processes and set up conjunctivitis, bronchitis and a distinctly reddish swelling of the face and forearms. Spitzer reported three cases in Vienna (1924). Wintersteiner, in 1893, drew attention to the case of a worker who was obliged to bend over his work on account of shortsightedness and in consequence numerous minute particles of amber were found to have penetrated the cornea. Rambousek, on the other hand, recalls the danger of lead poisoning presented by the use of lead blocks on which the amber is cut.

The use of solvents referred to above in the manufacture of varnishes and compressed amber must also be taken into account as possible sources of danger. Workers are further exposed to the risk of poisoning, fire and explosion.

Aminophenols


Several aminophenols are known: they are slightly acid bodies, like phenol, and at the same time bases, as they form salts with acids. They further act as powerful reducing bodies, and precipitate gold and silver from their salts. Their special use is in photography or the preparation of synthetic organic colours.

When in the benzene molecule a monovalent group OH (hydroxy) is substituted for H, phenol is formed (see that article). If OH is substituted twice for H, diphenol is formed. On considering the symmetry of the benzene nucleus, however, it will be seen that the substitution can be made in these different ways yielding isomers (with the same percentage composition and the same formula; ortho-diphenol or "pyrocatechene", meta and para or "hydroquinone", the physical and chemical properties of which differ by reason of the different positions of the same atoms in the three molecules, when the substitution extends to three atoms, the triphenol of C₆H₄(OH)₂, 1, 2, 4, is "pyrogallol" or pyrogallic acid. If the monovalent radical NH₂ is substituted for a hydroxyl group OH the aminophenols result with the three isomers: ortho, meta and para, of which the last is the most used.

When for two groups of the monovalent radical two hydroxyl groups of a molecule of triphenol are substituted diamino-phenol, for instance, is obtained (ortho-paradiaminophenol).

The paraminophenol yields another body when an H of the NH₂ is replaced by the monovalent radical CH₃ (methyl). The monomethyl-paraminophenol thus obtained is an amine which, with the acids of the crystallisable salts, and particularly with sulphuric acid of the sulphates, yields sulphate of monomethyl-paraaminophenol, which is the "metol" so much used in photography.

"Iconogene" is derived in a rather more complicated way of which it is not necessary to speak.

These bodies called "developers" have the property of reducing silver salts when acted on by light. They are in common use to-day, but whilst hydroquinone gives hardly any trouble, the other aminophenols may affect persons manipulating them. (See article "Photographic Plates").

Industrial Processes

The preparation of the hydrochloride of diamino-phenol which is taken as a type, comprises the following series of operations:

Dinitrophenol is introduced into a wooden vat with commercial hydrochloric acid and mother liquors of crystallisation very rich in hydrochloric acid, then with small quantities of white cast-iron filings. The acid, decomposed by the iron, gives off hydrogen, which reduces the dinitrophenol; basic diamino-phenol is formed, which combines with the hydrochloric acid to form the hydrochloride. When the reaction has ended, the liquid is run into wooden vats; a solution of common salt is added to precipitate the hydrochloride of diamino-phenol. The precipitate collected in a bag is placed to drain on flannel filters.

The greyish white mass obtained is dried on stoneware filters, or filtration is carried out under a vacuum. The
crude salt, after solution in hot water, is filtered over animal charcoal. Hydrochloric acid is added to the liquid collected in stone vats and in this the hydrochloride is only slightly soluble and crystallises out. The crystals, dried on a filter under a vacuum, are redissolved in water; another filtration and drying on a filter under a vacuum, areuble and crystallises out. The crystals are scratched, giving rise to small haemorrhages which become covered with crusts. The eczema may extend to the chest, the neck and the face; sometimes it occurs on the genital organs. The workmen suffer from an intolerable pruritus preventing rest and sleep. One old worker, on being questioned by Lenoble, complained that he had had no proper rest or sleep for six months, he would have been glad to have been able to give up the manufacture of aminophenols.

All the commoner forms of treatment are almost useless. The only way of effecting a cure is to give up all contact with the materials in question. Acclimatisation does not take place; the workmen who recover and return to work at once succumb a second time in the same manner.

The individuals who generally stand the work best are those of spare physique and nervous temperament. Those who suffer most, on the contrary, are the fat, the alcoholic, the tubercular and syphilitic — in short, those whose resistance is diminished, or in whom elimination is poor, or whose skin is easily irritated. Lenoble has described several cases of susceptibility in a French factory, as well as other cases among photographers. The latter are also attacked (but not so frequently as those who manufacture the materials) with plaques, papules, on the back of the hands, and excoriations and vesicles on the fingers and hands.

The alkalinity of the baths has been shown not to be the cause because diaminophenol is used in neutral baths, and because, further, in the process of manufacture the dermatitis is worst where the salts are constantly acid.

**Prevention**

Prophylaxis consists in covering the vats with wooden covers, providing a shaft to carry away the fumes to the outside air, avoiding all contact with products likely to set up the condition; provision, consequently, for the workmen, of the necessary tools, furnished with long handles, and kept clean; provision of rubber gloves and respirators for persons employed in sieving; provision of proper washing facilities, etc. In spite, however, of all measures taken, subjects particularly sensitive cannot continue to work.

**Risk of Poisoning**

The manufacture of diaminophenol and paraminophenol exposes the workmen to the acid vapours of hydrochloric acid when the process is commenced, and, to a slight extent, subsequently, during stoving; though during this latter operation exposure to risk is very short.

In the manufacture of metol, the workmen may be exposed to the vapours of methyl sulphate, which is excessively irritating to the eyes and bronchial mucous membrane.

Workmen employed in preparing diaminophenol find themselves exposed, when charging the vats, in more or less direct contact with dinitrophenol, which turns the skin yellow in a degree only slightly less than that of picric acid.

Erich Meyer, in his researches on intoxication by nitrobenzene (see that article), has found in the urine of persons poisoned with this substance, the intermediate bodies p. nitrophenol and p. aminophenol, which are said to cause methaemoglobin.

Although no effects other than localised skin irritation, of not so much importance, are attributable to contact with the acids, and the characteristic yellowish colourisation of the skin to diaminophenol, without specific illness, the use and manufacture of the aminophenols set up a dermatitis remarkable for its relative frequency, tenacity and intensity among those coming into contact with them; and more rarely, but of a very tiresome character, among photographers using these materials in developing.

This eczema, according to Lenoble, shows itself within a week of taking up the work in the factory. The skin, first at the root of the nails and in the interdigital spaces, and later on the back of the hand, the wrist and forearms become inflamed, swell and are painful. If work is continued, papules and vesicles may appear which ulcerate either spontaneously or when they are scratched, giving rise to small haemorrhages which become covered with crusts. The eczema may extend to the chest, the neck and the face; sometimes it occurs on the genital organs. The workmen suffer from an intolerable pruritus preventing rest and sleep. One old worker, on being questioned by Lenoble, complained that he had had no proper rest or sleep for six months, he would have been glad to have been able to give up the manufacture of aminophenols.
Eczema and dermatitis, whether occurring amongst those who manufacture the products or amongst photographers, are statutorily notifiable in the Netherlands. They are included in the diseases for compensation under Workmen’s Compensation Acts in those countries which schedule poisoning or its sequelae from nitro and amido derivatives of benzene and its homologues.

**Bibliography**


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**Ammonia**


**Properties**

Ammonia is a solution in water of ammoniacal gas, which at ordinary temperature is a colourless gas with a very strong and pungent smell having the formula NH₃ and a density of 0.596. It is very soluble in water, which dissolves 1,148 times its volume at 0°C and 760 mm. It can be condensed at an ordinary temperature by compression into the liquid state, boiling at —33.7°C and solidifying at —75°C. The evaporation of the ammoniacal liquor is accompanied by a great absorption of heat; on this account it is employed in refrigerating machines.

Atmospheric air always contains a certain quantity of salts of ammonium (up to one part of salt to 10,000 parts of air). The saturated aqueous solution of ammonia, which has a density of 0.835, is generally employed instead of the gas itself since it is more easily dealt with. It is caustic, has a strong alkaline reaction and neutralises the strongest acids forming salts of ammonium.

**Production**

The principal sources of ammonia are: night soil and sullage water; the nitrogen from combustible fossils and atmospheric nitrogen.

Night soil contains nitrogen especially in the form of urea which when acted upon by a ferment becomes carbonate of ammonia; the latter when distilled with lime gives ammonia. A cubic metre of sullage water can in this way furnish 2 to 4 kg. of ammonia.

These materials are brought to special factories where they are left for a month in large basins called night soil depositories (dépotoirs). Sludge is deposited which on being dried becomes a manure called “poudrette” (dried and powdered night soil). The decanted liquid which contains ammonium carbonate is distilled with or without the addition of lime in apparatus similar to that used for obtaining ammonia from coal. The gases which escape in the process of distillation have a very offensive smell and should be led away and destroyed.

The recovery of ammoniacal liquor which is deposited in the vats, scrubbers and washers of gas and coke works is of great importance. That, with the nitrogen of the air, is the source of nearly all ammonia used in industry.

At gas or coke works ammonia is produced in the form of sulphate of ammonia, concentrated liquor or caustic ammonia. The last two are obtained by treating the crude liquor in apparatus similar to that of Savalle for alcohol (see that article). Lair’s apparatus consists principally of a tower with shelves on which milk of lime is spread, which displaces the ammonia. Mallet’s tower is supplied with a mechanical stirrer which prevents fouling by the lime.

The ammonia gas on leaving the distilling apparatus is collected in water or is liquefied by compression in steel cylinders. In the last case it is necessary to subject it first to careful purification by washing it with petrol and a solution of soda, then passing it through animal charcoal and lastly drying it with quick lime. The recovery of ammonia from the gases of blast furnaces is actually carried out by a process almost the same as for lighting gas.

The transformation of atmospheric nitrogen into ammonia can be carried out by means of metallic nitrates, or by passing the atmospheric nitrogen through calcium cyanamide, or by direct union of nitrogen and hydrogen in the presence of a catalyst.

The only industrial application of the first method is that of Serpek, in which a mixture of bauxite (impure natural alumina) and charcoal is passed into a furnace provided with a long tube heated electrically and traversed by gas from a gas generator (N+CO). The reaction with nitrogen gives nitrite of aluminium and carbonic oxide. The nitrite of aluminium when treated with soda gives ammonia and a pure aluminate of soda which can be used in the preparation of alumina.

Calcium cyanamide (see that article) prepared by means of atmospheric
nitrogen and carbide of calcium decomposes into ammonia and carbonate of lime when acted upon by water. The process is carried out in an autoclave at a pressure varying between 3 and 10 kg. per square centimetre.

Direct combination of nitrogen and hydrogen is carried out according to the process of Haber, especially in the German works of Oppau and Merseburg. These works, in order to prepare gas for the purpose of catalysis, start with hydrogen which has been water-gased by water:—

— "Gas (Industrial)" and air. The solution of carbon monoxide is oxidised into anhydrous dioxide by steam in the presence of a catalyst and the carbonic acid is dissolved in water under pressure. Any traces of carbon monoxide are removed by treatment with an ammoniacal solution of copper formate. Hydrogen and nitrogen are the only gases left and the mixture is compressed at 200 atm., then passed into catalysing tubes heated to 550° C. The catalyst consists of iron which has been specially treated and contains very little alumina. The yield being only from 4 to 5 per cent. of ammonia for each passage through the catalyst, it is necessary for the process to be carried on in a closed circuit, that is to say, the residuary gases repass to the catalysing tubes after the ammonia formed has been dissolved by water and amounts of nitrogen and hydrogen have been introduced into the circuit corresponding to but not exceeding the quantity of ammonia formed. In this way a 20 per cent. solution of ammonia is obtained.

In order to increase the yield of ammonia, Claude compresses the gases at about 1,000 atm. before introducing them to the catalysing tube. As the result of the great pressure, the ammonia obtained is liquid; it is collected as such and not in the form of a solution. Claude produces nitrogen by distillation of liquid air, and he has proposed to obtain hydrogen from the gas of coke ovens by freezing out the other congealable constituents. He has also under consideration using gas from coke ovens for synthetic ammonia. In a similar process an apparatus is used by which hydrogen is extracted from water-gas.

Some Italian works employ a process attributed to Casale. The gases pass under a pressure of about 750 atm. into special electrically heated converters supplied with apparatus for varying the temperature. This work is also carried out in closed circuit and gives ammonia in a liquid state. Hydrogen and nitrogen are produced in a special way. Electrolysis of water gives hydrogen, of which an excess is mixed with air followed by combustion; there results synthetic water and a mixture of hydrogen and nitrogen which is passed to converters.

The process of Jausser, which is also employed in Italy, only differs from the process of Casale in structural details. From the hygienic point of view it presents the same advantage. (See figure, page 113.)

**USE**

Liquefied ammonia is supplied for industrial use in steel cylinders. The aqueous solution of ammonia is also very often used, known as ammonia or volatile alkali. The chief uses of liquefied or distilled ammonia are: the preparation of sulphate or chloride, or nitrate of ammonia; the manufacture of nitric acid (see that article), of soda by the Solvay process, of urea, of artificial ice, of cyanides, etc. It is also employed as a reagent in laboratories, in pharmacy and in numerous operations of the chemical industry (organic products: aminated derivatives, etc.).

Hydrazine (N₂H₄), utilised in aqueous solution as hydrate of hydrazine, N₂H₂·OH, has not yet taken its place in practical industry. For nitrate of ammonium and methylamine, see article "Explosives".

Finally, it must be remembered that Claude has drawn attention to the interest, from the viewpoint of producing artificial manures, attached to the transformation of synthetic ammonia into ammonium chloride by the aid of chlorine lost in immense quantities in the Solvay soda industry.

**SOURCES OF POISONING**

(a) In the course of the manufacture of ammonia, workers are exposed to ammonia vapour; to fumes of sulphuric and of metaphosphoric acids; to offensive smells set free when ammonia vapour comes into contact with acid fumes, such as sulphuric acid, and when non-volatile compounds of ammonium are disintegrated by caustic alkalis; to pyridine, phenol and tar (by-products of ammonia manufacture); to sulphured hydrogen and compounds of cyanogen. Workers may also be exposed to the action of lead, etc.

(b) In the course of certain industrial processes or in the use of ammonia, risk is associated with handling glass or
of calcium, of colours, such as indigo and amaranth, and of lacquers; in dyeing phosphate and sulphate of ammonia. Great quantities in the gas-lighting industry when great amounts of ammonia are set free, especially when tarry water is used and when it is distilled; with preparing phosphate and sulphate of ammonia due to the combined action of lighting gas, sulphuretted hydrogen and cyanogen compounds. There is also exposure in refineries for petrol and certain industrial oils which contain alkalis (0.8 to 2 per cent. of caustic soda, 1.5 per cent. ammonia); in the Solvay soda industry; in glue works; in the manufacture of explosives, of nitro-cellulose, and of artificial silk; in the preparation of salts of ammonia. Ammonia is further set free in tanneries, and certain industrial oils which contain alkalis; in making and working of refrigerating plants wherein ammonia gas under pressure is used in the apparatus; in sugar refineries; in making animal charcoal; in the manufacture of carbide of calcium, of colours, such as indigo and amaranth, and of lacquers; in dye works; in bleaching with peroxide of hydrogen; in the treatment of Tussore silk after the acid bath of dilute hydrochloric acid, hydrogen; in the treatment of Tussore silk with sulphuretted hydrogen and cyanogen compounds. The absorption is more complete if the exposure is of short duration and, if the exposure is prolonged, the quantity of gas absorbed does not diminish in a marked manner. The effects do not vary very much whether the ammonia is inhaled by the nose or by the mouth. Whichever way it is, most of the ammonia is rapidly absorbed by the mucous membranes and by the saliva. With weak concentrations any action upon the throat and the deeper air passages is slight.

A strength of 0.1 mg. per litre of air produces only a slight irritation and a strength of 0.25 mg. can be borne without injury, but not without discomfort. With dogs an acclimatisation to the action of ammonia has been observed with inhalations, repeated over two to three weeks, of air containing 0.8-1.0 mg. per thousand of this gas. According to Ronzani 0.1 mg. is tolerated for 30 days by guinea pigs without injury, whereas they react with a dose of 0.4 mg. and show diminished resistance to infections. The opinion given by Hober (1913) that the lungs are impervious to ammoniacal fumes has not been confirmed.

A strength of from 2 to 4 mg. per litre, inhaled by animals not accustomed to it, causes serious irritation with ulceration of the conjunctiva and of the respiratory passages, oedema of the larynx, pulmonary haemorrhages, and pneumonia of an atypical type.

STATISTICS

Industrial poisonings are not common. They occur mostly among workmen at gas works employed in the sublimation of ammonium carbonate and generally in the preparation of salts of ammonia. However, according to certain experts the poisoning is to be ascribed to fumes containing sulphuretted hydrogen and compounds of cyanogen rather than ammonia.

In the United States, Fairbrother, in 1887, reported three fatal cases and one serious poisoning by ammoniacal fumes among four workmen employed in repairing a refrigerating apparatus in a brewery.

In Great Britain the following cases have been reported: 1914, 4 (1 fatal); 1917, 4 (1); 1918, 6 (1); 1919, 8; 1921, 9 (1); 1922, 8 (1); 1923, 5 (1); 1924, 1.

In Switzerland, the Government department for the prevention of accidents had reported to it a case of poisoning in 1919 and another in 1920; one case of ulceration was also reported in 1918, two in 1921, and five cases from 1922 to 1925.

SYMPTOMS

Generally the cases notified only present lesions of the skin, such as irritation and caustic wounds, which may nevertheless reach the stage of a burn of the second degree, affecting exposed mucous membranes, eyes, throat, and upper respiratory passages, when caused, for example, by ammonia gas escaping from refrigerating apparatus. If the fumes are inhaled in great quantity, an acute condition may supervene with the gravest of symptoms extending even to pulmonary oedema (2 cases, Hamilton), and sometimes to a fatal issue (one case in a
Dutch brewery and another in an American one). From the industrial point of view, chronic poisoning is not of importance. The general troubles reported are due much more to the action of compounds of sulphur, e.g. ammonium sulphide and sulphuretted hydrogen.

The action of ammonia upon the eyes deserves special attention. Conjunctivitis may be accompanied by the formation of pseudo-membranes, and days later became very deep with increase of intraocular pressure followed by perforation and hernia of the iris; Abadie, Denig and other experts quote similar cases with diminution and even loss of sight. These cases show that if ammonia infiltrates slowly into the corneal tissue, it causes very serious deteriorations after it has penetrated. Trantas has studied the case of a workman who, following a long exposure to the action of ammonia vapour, had a corneal lesion closely localised in cases caused by the strong action of ammoniacal fumes lesions of the cornea may result. At first the reaction may seem to be slight, but later, after one or two weeks, a parenchymatous lesion appears and possibly softening of the tissues.

Pichler mentions chronic conjunctivitis among grooms obliged to remain for long periods in ill-kept stables. Troussseau has recorded the case of a mechanic at an ice factory who had ulceration of the cornea, which twelve to the area bounded by the palpebral border.

As regards dermatitis caused by ammonia compounds, it is sufficient to recall that the nitrate in certain conditions of temperature and subdivision depending also on the peculiarity and predisposition of the individual, causes dermatitis, accompanied by unbearable itching, especially at night, and erythema. These lesions are, however, sufficiently well defined. (Case of P. White, 1916.)
Hygiene

Consideration must be given to the raw materials; to their storage in impermeable and airtight vessels, to preventing the escape of offensively smelling fumes, and the contamination of the subsoil. Closed receptacles only must be used. Efficient exhaust ventilation must be installed over apparatus which gives off fumes and vapours. Steps must be taken to prevent the escape of any noxious gas, and for thorough condensation of gaseous ammonia. Gases not condensed should be burned; and the workshops be kept thoroughly ventilated. Chimneys should be high; and close supervision exercised over the discharge of waste waters. Apparatus and joints should be carefully luted; and gases which cannot be dissolved in water should be condensed in a vessel containing a dilute mineral acid.

From a practical point of view, it must be borne in mind that it is not desirable to conduct offensively smelling fumes to a furnace, for the sulphuretted hydrogen will give troublesome sulphurous acid; this method should then only be used after having absorbed the sulphurous fumes by lime, or used them to produce sulphuric acid.

Legislation

The Spanish law excludes boys of less than 16 years and women of less than 21 years from ammonia works; in Greece boys of less than 16 years and women of less than 18 years are excluded from compressed gas factories (compressed ammonia); in Italy boys of less than 15 years and women of less than 21 years are excluded from ammonia works as well as from compressed gas factories.

In Holland, in places where ammonia is given off in quantities considered injurious by the factory inspector, young persons of less than 18 years and women are only admitted on condition that they obey the inspector’s orders for preventing danger of poisoning, e.g. an obligation for each worker to have a medical certificate, not to eat in the workplace, and not to keep food or pass his spare time there (art. 33, cat. P, of the law of 1920). (See also article “Alkalis”.)

Special legislation laid down by Great Britain (Chem. Works, 1922) deals, among others, with factories where ammonia and salts of ammonia are made.

The injuries caused by ammonia are compulsorily notifiable in France and Holland, and compensated in Finland, New Brunswick, and in Switzerland; eye lesions only receive compensation in Argentina, Bolivia, and Brazil. ***

Amyl Acetate


Amyl acetate, of which the formula is CH₃COOC₂H₅, is in its pure state a colourless, light, neutral liquid with an agreeable smell resembling that of ripe pears. Its specific gravity is 0.875-0.886 at 15° C. and its boiling point is 138-139° C. Searcely soluble in water it is soluble in alcohol and ether. The crude acetate has usually a pale yellow colour and its disagreeable odour somewhat resembles that of crude amylc alcohol. Its density and boiling point vary. The commercial article generally contains as impurities, alcohol, amylc alcohol, acetic acid, sulphuric acid and hydrochloric acid.

Preparation.—Amyl acetate is prepared by heating and distilling a mixture of ordinary amylc alcohol, sulphuric acid and acetate of soda or calcium, and purifying the distillate by washing with a solution of bicarbonate of soda. The final product is rectified.

Use.—Amyl acetate is used as a solvent in preparing the basis of photographic and cinematographic films (dissolving nitrocellulose); in making varnish (acting on nitrocellulose or celluloid); in making lacquer (used in lacquering metal or jewellery); in making and in special products for rendering aeroplane wings impermeable (see article “Tetrachlorethan, “); in preparing patent and buff leathers; for special processes in cleaning and graining leather, for the pastes used in the manufacture and finishing of boots; in the manufacture of art glass; in the making of incandescent electric lamps, dry batteries and accumulators; in the preparation of fruit essence, etc.

Absorption.—It is absorbed by the respiratory passages. Lehmann (1913) found by experiments upon cats that 29 mg. per litre of air inhaled for nine hours and a half produced no effect; that 28 mg. during four hours and a half to six hours produced only slight symptoms of irritation; 35 mg. caused loss of equilibrium at the end of three hours and narcosis at the end of seven hours. It has not been found to have a fatal effect. In man a strength of 60 mg. in 12 cubic metres of air produces at the end of an hour some slight symptoms of irritation (cough, dryness of the throat) which are however easily borne. These
slightly irritating to the skin and so favours the onset of dermatitis.

Lacquering by the cold process in badly ventilated places exposes the workers to the action of the disagreeable vapours of amyl acetate.

The vapour causes nervous symptoms, pains and heaviness in the head, giddiness, nausea, torpor, digestive troubles, palpitation, inflammation, and irritation of the respiratory system, a sensation of heat and slight fainting attacks.

No case of chronic poisoning has been reported. Koelsch, in the course of an enquiry made in 1912 to determine the harm caused by amyl acetate, came to the conclusion that workers only complain at the commencement of work and never when the workshop is thoroughly ventilated. The symptoms which he experienced himself were a sensation of oppression of the chest, fatigue, cough, pains in the head and giddiness which disappeared at the end of two to three hours. Habituation to the action of this product has not been observed. On account of the high price it is often replaced by benzol. In order to determine the toxic action of amyl acetate, one must take into account the concomitant effect of the other elements which go to make up lacquer (acetone, benzene, amyllic or methyl alcohol, etc.).

Among the substitutes which have been proposed may be mentioned amyl formiate, cyclohexanolformol, methyl-cyclohexanolformate—which does not seem to be so inoffensive as cyclohexanolacetic— and above all cyclohexanolacetic which though about three times more poisonous is at the same time three to five times less volatile than amyl acetate.

Hygienic measures are concerned with the collection and removal of the vapour.

No special legislation exists.

### Amyl Alcohol


Eight amyllic isomeric alcohols are known. The most important is the amyl alcohol of fermentation, got from fusel oil to which it imparts its burning taste and nauseous odour. It is a liquid with specific gravity of 0.81, boiling point 131° C., and solidifying at 134° C.

It possesses a strong bactericidal action and is highly poisonous. The serious effects of alcoholism are attributed, by certain authorities, to this alcohol which is present in most liquors.

Amyl alcohol is used in the manufacture of amyl acetate (see that article), to dissolve acetate of cellulose, and in the preparation of isoprene and synthetic india-rubber, in the preparation of certain aniline colours, certain fruit essences, amyl nitrite and valeric acid. The latter when transformed into a sodium salt and treated by sulphuric acid and alcohol gives valerianic ether, the odour of which is characteristic, resembling raspberries. Amyl alcohol is also used in the production of amyl acetate, having an odour of pears or bananas. It is used alone or mixed with ethyl alcohol in the manufacture of powder and explosives and it is present as an impurity or a by-product in the manufacture of chloroform, etc.

Of all forms of alcohol used amyl alcohol is the most toxic; 1.50 grm. suffices to kill an animal averaging 1 kg. in weight, while 7.75 grm. of absolute ethyl alcohol and 6 grm. of methyl alcohol are required to achieve the same result. Fumes of amyl alcohol are more highly toxic than those of the alcohol ether mixture. The toxicity of amyl alcohol increases when evaporation is favoured by simultaneous evaporation of ether or ethyl alcohol.

The fumes cause very severe and uncomfortable irritation of the throat, headache, vertigo, and cannot be tolerated in repeated doses.

Injuries due to amyl alcohol an compensated in Finland.

For further information see article “Ethyl Alcohol.”

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**AMYL ACETATE**

**AMYL ALCOHOL**
**Amylene**


Amylene, the symbol of which is $C_4H_8$, belongs to the group of olefines (non-saturated hydrocarbons). It is a colourless liquid with an odour resembling petroleum spirits. It is volatile and very inflammable. Its boiling point is 37.30° C. and its specific gravity is 0.667.

Industrially amylene is got from a mixture of different amylene isomers, containing pentane, by heating fusel oil in presence of zinc chlorides. This product, commonly but incorrectly designated “amylene”, is a colourless liquid with a particular odour very volatile and inflammable; its specific gravity is 0.660 and its boiling point between 30 and 40° C.

In 1917, in a Dutch factory where “blue gas” was produced using as basis hydrocarbons with a high boiling point, several workers were found to suffer from violent pains in the back, stomach and chest and from vomiting. A strong odour of gas was noted in the workshop containing the amylene tank and the compressor.

Analysis of the atmosphere revealed the presence of poisonous volatile substances, principally ethylene, amylene and pental. The first and last of these exercised a narcotic action, whilst the amylene acted as an irritant (giving rise to cramp).

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**Anguillulosis**

French: *Anguillulose.* — German: *Anguillulosis.* — Italian and Spanish: *Anguillulosi.*

The *anguillula intestinalis* (or *Asterocoralsis; Pseudorhabditis stercoralis* or *intestinalis; Rhabdonema intestinalis* or *Strongyloides*) is a parasite widely dispersed through the whole of the torrid zone in Asia, in the Indian archipelago, in America (Brazil, Panama, the Antilles) as well as in Europe where it chiefly affects miners.

The etiology of this disease is quite analogous to that of ankylostomiasis. The experiments of Durma, Gonder, Loos, Hermann, Marzocchi, and Perroncito have long since proved that the mode of entry of this parasite is principally by way of the skin and that entry by the mouth is very much less frequent. It would even appear that larvae introduced by way of the gastric system do not enter the intestine directly, but traverse the wall of the digestive tube and thus arrive in the general circulation and behave similarly to larvae which have penetrated by way of the skin.

Perroncito, who made a study of this parasite simultaneously with the ankylostoma at the time of the great St. Gothard epidemic, was led to enquire if the *anguillula intestinalis* and the *pseudorhabditis stercoralis* belonged to the same species or two different species, or if, as Grassi and Parona thought, the *pseudorhabditis* was the demorphobiotic form of the anguillula. It is now known that there are two kinds of adult anguillulae: a parasitic or intestinal form which comprises only parthenogenetic females, and the free form — stercoral or rhabditoid — which develop in faecal matter outside of the human body. Male and female forms of this kind are observed.

The parthenogenetic females of parasitic form are generally situated in the wall of the intestine itself and the eggs are often laid in the chorion or the glandular tubes. Teissier has proved that the embryos can pass into the circulatory system instead of maturing in the intestine.

Embryos or eggs evacuated with the faeces develop into rhabditoid larvae, which quickly reach the adult stage at a temperature above 20° C., and represent the second free form (sterctal). Copulation takes place outside the body. The female (ovoviviparous) presents in the uterus eggs enclosing a completely formed embryo and liberates rhabditoid larvae which are soon transformed into strongyloid larvae.

**Pathogenesis**

The anguillulae (female) penetrate by breaking their way into the *muscularis mucosae* of the intestine, exercising an irritant action resulting in destruction of the epithelium, congestion of the blood vessels, etc., and creating a mode of entry for secondary infection. It is probable that, apart from the process of setting up anaemia which it exercises in obtaining nourishment, the anguillula also exercises a toxic action analogous to that of the ankylostoma; it is however difficult to determine just what rôle is to be ascribed to the anguillula, since it is very often associated with the ankylostoma.
intermittent diarrhoea, sometimes blood-stained, and patulous bowel movements (noted by Perroncito amongst the workers).

Clinically its presence is manifested by digestive disorders, enteritis with intermittent diarrhoea, sometimes blood-stained, and pain, by fairly marked anaemia and a rise in temperature (noted by Perroncito amongst the St. Gothard workers).

Prophylaxis

Prophylactic measures to be adopted are those described under ankylostomiasis (see that article).

Aniline


Properties

Aniline (formula $C_6H_5 - NH_2$) is derived from benzene; it is obtained by replacing one of the hydrogen atoms of the benzene ring by an amido group. Unverdorben was the first to prepare it in 1826 by dry distillation of natural indigo; in 1824 Runge separated it from coal tar. The first preparation effected by reducing nitrobenzene (using ammonia sulphate) was carried out in 1842 by Zinin; but the technical preparation and use, on a big scale, of aniline dates from about 1860, and corresponds to the development of the industry of coal tar dyes.

Pure aniline, freshly distilled, appears as a colourless, oily liquid, gradually turning brown when exposed to the air; it possesses a peculiar slightly aromatic smell of its own. Its specific gravity is 1.0254 at 15° C., its boiling point is 189° C. It has not yet been possible to apply industrially such other processes as electrolytic reduction, reduction by sodium sulphide, preparation by means of chlorobenzene and ammonia under pressure and at a high temperature.

Preparation, by the ordinary process of reduction, is carried out technically in an apparatus chiefly composed of a vat with a stirrer, a cooling vessel with reflux and a pipe for carrying off the steam. The injection of steam heats the mixture and this helps on the reaction at the start and makes it possible to empty the apparatus when the process is concluded. The apparatus, which is large enough to treat several cubic metres at a time, comprises also tanks, for decanting and holding aniline, and monte-jus (pumps). The process is regulated by gradually adding nitro-benzene and the proper quantity of iron filings into the disintegrator. Reduction takes about ten hours. Salt or lime is then added which releases the aniline, then the current of steam is increased in intensity so that the released aniline is swept through the cooler into a tank, where it accumulates. For this purpose steam is used which is charged with aniline that has been produced from cauldrons fed with water already containing this product and coming from the tanks into which it has been decanted. In this way loss owing to...
the solubility of the amine in water is avoided. The same process is used in the manufacture of derivatives, in order to recover any aniline which has not entered into reaction.

Crude aniline after decanting is transferred into a reservoir by means of special pumps.

The crude aniline is purified by distillation under reduced pressure at about 170° C. in apparatus of great capacity. The first and last parts of the distillation, composed respectively of mixtures of aniline and benzene, and of aniline and water, are purified by fresh distillation.

Preparation of the homologues of aniline is carried out in a similar manner by reduction of the corresponding nitro-derivatives: nitro-toluences and nitro-xylences. In the preparation of xylidine, starting with a mixture of different nitro-xylences, separation is effected of the isomeres contained in the commercial xylidine, which is first procured. The para- and meta-derivatives have as a matter of fact special technical importance. The separation is done by transforming the products into sulphonic acids, or into salts and then utilising variations in the solubility of these bodies.

**Uses**

Aniline, its homologues and derivatives are almost exclusively used in the dye industry. It is used in a small way for pharmaceutical synthetic products (antifebrin; preparations of phenetidine and pyrazolone). Aniline is further used to a limited extent in the preparation of rubber, as a solvent and an accelerator when vulcanising by heat. In both cases the fumes of aniline which are set free have been known to give rise to poisoning. The use of aniline in the form of aniline salt (chlorhydrate) is more common (see later): it is used in aniline black dyeing by oxidation on the fibre. In that work poisoning also occurs (see later). Other uses to which it is put, such as the manufacture of black dyes for leather, are of secondary importance.

Aniline is used in the preparation of colouring matters, either directly or after having passed through a series of transformations into intermediate products by means of substitutions in the amic group or in the nucleus.

The most important products both as regards the technique and the hygiene of industry are the alkylated and arylated amines (toluidines) among which must be mentioned: mono- and di-methylaniline; (C₆H₅) — NH — (CH₃) (C₆H₅) — N — (CH₃); mono- and di-ethyl aniline (C₆H₅) — NH — (C₂H₅), (C₆H₅) — N — (C₂H₅); benzylanline (C₆H₅) — NH — CH — (C₆H₅); and diphenylamine — (C₆H₅) — NH — (C₆H₅).

The alkylated and arylated amines are especially used for the preparation of dyes derived from triphenylmethane (see further on) and of diphenylamine. Their physical and toxicological properties are similar to those of aniline and its homologues. They are obtained by heating in an autoclave to 200°-250° C. the hydrochlorate of aniline with the corresponding alcohols, or sometimes by heating aniline with halogen compounds, such as chloride of benzyl. In order to prepare diphenylamine, one simply has to heat a mixture of aniline and hydrochlorate of aniline.

The most important by-products obtained by substitution in the nucleus are sulphonic acids (C₆H₅SO₃H), which makes possible the manufacture, among others, of azo dyestuffs and nitro-aniline (NO₂C₆H₅NH₂). As regards sulphanilic acids it must be pointed out that the derivative (metanilic acid) is directly prepared by the reduction of metanitro-benzensulphonic acid without passing through the aniline stage; the para-derivative, sulphanilic acid, is obtained by the furnace process, by heating sulphate of aniline to 200°-250° C. on sheet iron in a furnace which is generally in the shape of a tunnel. When the transformation is completely effected, the mass is dissolved in water with the addition of soda; the excess aniline is removed by a current of steam, and then purified by crystallisation. This process is equally useful for the manufacture of other sulphoaniline acids, such as naphthionic acid. It causes a liberation of aniline vapours which must be carried off by an exhaust draught.

Sulphonic acids themselves are substances soluble in water, and not as a rule toxic; they are non-volatile and present little affinity for fats. Thus they are not dangerous and have but little interest from the point of view of industrial hygiene.

Of the two nitro-anilines, the meta-derivative, obtained by the reduction of meta-dinitrobenzene by means of polysulphide of sodium, is of technical importance.

Reduction, as well as filtration of the sulphur, which separates out during the reaction, is carried on in boiling water in a closed boiler. Efficient exhaust draught must be connected to the apparatus wherein these operations
are carried out, for the first and final products are both very poisonous, but may easily be caught by steam.

*Paranitranilin* can also be obtained by nitrating formanilide or acetyllyl and then saponifying, for the acyl group protects the amido group. The elimination of orthotranilin, which is formed simultaneously, is effected by washing with hot water, but as this isomer may be carried off by steam this operation may be dangerous. The risk of poisoning may be avoided by furnishing the filter with a cover or with a cowl communicating with an exhaust draught.

To avoid the setting free of dust during the grinding and packing of the finished product, it is necessary to protect in the same way the mills and finished during the grinding and packing of the exhaust draught.

Commercially, aniline, its homologues and derivatives are used for the preparation of two large groups of *colouring matters*: the dyes of di- or tri-phenylmethane and azo dyes; the preparation of aniline salt for direct dyeing belongs to a class by itself.

**Dyes of Di- and Tri-Phenylmethane**

This group of dyestuffs, which constitutes the "aniline dyes" in the strictest sense of the term, is characterised by a combination of two or three phenyl groups attached to the carbon atom of methane.

\[
\text{H}_4 - \text{C} \quad \begin{array}{c}
\text{C}_3 \text{H}_4 - \text{NH}_2 \\
\text{C}_2 \text{H}_4 - \text{NH}_2 \\
\text{C}_3 \text{H}_4 - \text{NH}_2
\end{array}
\]

The development of the aniline industry dates from the preparation of derivatives of this group and particularly from the discovery of aniline red (fuchsin) by Nathanson and Hoffman (1856-1858), as well as the determination by Hoffman, Perkin, Verguin, etc., of its composition and the chemical conditions under which it is formed.

The preparation of its derivatives constitutes another very important part of the industry of colouring materials. This group, in addition to the primary colours, red (fuchsin), violet (crystal violet), blue (aniline blue, and light blue) and green (malachite green, Victoria green, and light green), includes colouring matter obtained by the substitution of alkylated and arylated groups for the hydrogen atom of the amido group. These last colours are obtained by the introduction of alkyl or aryl groups into the finished product, or by treatment of the corresponding alkylated or arylated amines in place of the primary amines, such as aniline and toluidine.

The manufacture of these colours is sometimes done following the original process by oxidation, and sometimes by different processes of synthesis by condensation. Fuchsin is prepared exclusively in the first way, whilst the violets and greens are obtained by the second method. The process of synthesis of fuchsin by oxidation, in which the carbon atom of methane is furnished by the methyl group of toluidine consists in melting a mixture of aniline, para- and ortho-toluidine (Rötol) for the preparation of fuchsin with an oxidiser. The operation is carried out in a boiler at 160°-180° C. Violets and other colours are obtained in the same way, but by treating alkylated or arylated amines.

The arsenic process in which arsenic acid is used as an oxidiser is to-day completely replaced by the nitrobenzene process, on account of the dangers of poisoning which arsenic acid affords, as well as the residues and finished products which always contain a little. The nitrobenzene and nitrotoluene used at the present time with chloride of iron answer the purpose of oxidising agents and at the same time of raw material. As a matter of fact they replace one part of the aniline and of the toluidene. The melted mass is then composed of aniline, isomeric toluidenes and nitrobenzene or nitrotoluene. The fumes of amine which arise during the reaction mixed with the water which is formed are condensed in a refrigerator and are used afresh. When the fusion is completed, the hot and viscid mass, still containing aniline and toluidene, is run into a vat, where it cools and crystallises. Then the solidified mass is taken out, broken up, and boiled with water in a closed vessel and filtered while still hot. The colouring material is next precipitated by salting and purified by crystallisation. Fumes of aniline and toluidene may be set free, especially when the vessel is being emptied and the mass is being cooled. There is also a danger of this during the filtration of the hot solution. It was in the fuchsin-melting workshops that the first cases of aniline-cancer were reported.

The different processes of synthesis by condensation are nowadays much improved, as much from the chemical point of view as from the technical. They are based on the ease of condensation — it might even be said on
the tendency to condensation — which the aliphatic and aromatic aldehydes (formaldehyde, benzaldehyde) present. In fact they furnish quite easily their carbon atom of methane which brought in contact with amines and give colouring materials or their white derivatives. Melting by oxidation is omitted in most of these synthetic condensation processes.

Azo Dyestuffs

These constitute the second group of colours prepared by starting from aniline or its homologues and their derivatives, particularly from their sulphonic acids. This group includes very numerous derivatives characterised by the reunion of phenyl groups, diphenyls or naphthyls, by means of the azo group \((-\text{N} = \text{N}-)\).

This grouping is formed by diazotisation of aniline or other primary amine. Other aromatic nuclei may easily be fixed to one of the carbon atoms of the nucleus, which leads to the formation of colouring materials. With this object the primary amines can be used with one or several aromatic nuclei of alkylated or arylated amines, phenols, naphthols or sulphonic acids.

The amines capable of being diazotised and the compounds that can be used for this synthesis being very numerous, a large number of colouring materials can thus be produced. Thus, as it is possible to cause multiple fixations of groupings on several azo groups at a time (diazidised dyestuffs), the number of dyes which can be obtained by these methods is practically unlimited. Further, as the reactions of these syntheses occur fairly readily, and as they closely resemble one another, investigations in this domain have not presented particular difficulties. This is why this branch of the industry has developed very rapidly and to-day forms the principal branch of the manufacture of colours from tar.

The industrial preparation of these colouring materials is remarkably uniform. It is based on the transformation of aniline or of other aromatic amines into corresponding diazo compounds, a transformation which takes place under the action of nitrous acid in an acid solution. That is diazotisation. These compounds then quite easily combine with phenol, naphthols, aromatic amines, and their sulphonic acids and give the colouring materials (coupling). In the industrial process this operation is most often carried out in an apparatus arranged in three stages. The base or the corresponding chlorohydrate is first dissolved in a mixture of water and hydrochloric acid, in an open vessel furnished with a stirrer. The clear solution is run into the diazotising vessel which is placed below. It is cooled by means of pieces of ice, and the necessary quantity of hydrochloric acid and nitrite solution is added. Diazotisation occurs almost immediately. The compound with which the coupling is to be made is first dissolved in a vessel with a stirrer, then the solution is passed into the coupling vessel, into which the diazo base is also run. The separation of the dye generally takes place spontaneously, but it is facilitated and completed by salting and heating; then it is treated in a filter press to remove the mother liquor, and dried. In this way an almost pure commercial product is obtained.

In addition to the preparation of these two large groups of dyestuffs, aniline finds an important use in the synthesis of indigo by the glycine process. In this process the commencing product is phenylglycine obtained by the action of chloracetic acid on aniline.

Toxic Effect

Aniline exercises its toxic effect chiefly on the blood and the central nervous system. From the clinical and pathogenic aspect the most important phenomenon is its action on the blood and particularly on haemoglobin. In poisoning by aniline the oxyhaemoglobin of the red cells is transformed into methaemoglobin; marked cyanosis, which appears very rapidly in the clinical picture, is an early sign of progressive diminution in the power of the blood to absorb oxygen, to which are due the secondary symptoms of internal asphyxia, detectable first in the central nervous system. But it would not be accurate to ascribe all the symptoms of poisoning by aniline, and, in particular, the nervous symptoms, to secondary phenomena due to the transformation undergone by haemoglobin. As a matter of fact when poisoning is produced experimentally, these precise symptoms predominate, especially among herbivorous animals which possess comparatively good resistance to the action of aniline on haemoglobin.

On the other hand it is precisely by its action on the nervous system that poisoning by aniline, in the case of man and of animals, differs from other poisons which lead to the formation of methaemoglobin — poisoning by nitrates for instance. Contrary to what happens with the nitrates or carbon monoxide,
which particularly cause symptoms of internal asphyxia, aniline produces an early narcotic effect, as well as other fundamental phenomena affecting the central nervous system, before any sensible diminution in the capacity of blood for carrying oxygen is produced. Moreover, the specific action of aniline upon the nervous system seems to be sensibly feebler than that of nitrated aromatic bodies, which is probably due to its smaller affinity for lipoids.

According to fresh researches undertaken particularly by Heubner, Ellinger, and Lipschuetz, the action of aniline and most of its homologues and derivatives on haemoglobin is not to be attributed to these substances themselves, but to certain intermediate states of oxidation which occur within the organism. The same applies to the corresponding nitro-derivatives. In the body aniline undergoes especially oxidation into paramidophenol (OH — C₆H₄ — NH₂), with the intermediate formation of phenyldroxylamine (C₆H₅ — OH). Paramidophenol then unites with the sulphuric acid and is subsequently eliminated in the urine. This oxidation constitutes rather an anti-toxic phenomenon, since it leads to an acid compound which is comparatively slightly toxic and easily eliminated by the kidneys, namely: paramidophenol-sulphonic acid (NH₂ — C₆H₄ — O — SO₃H). On the other hand the intermediate products of this oxidation particularly phenyldroxylamine and paramidophenol possess to a high degree and in contrast with aniline itself, the property of reducing oxyhaemoglobin into haemoglobin. On the other hand, the transformation of haemoglobin into methaemoglobin is reversible. This inverse reaction is rapidly effected in the case of slight poisoning when the poison has been eliminated.

In addition to this action on haemoglobin, aniline, its homologues, and aromatic nitro-amino derivatives possess also the power of destroying red blood cells. This action shows itself comparatively slowly in serious and acute cases, that is to say, after the disappearance of the first serious symptoms, and is shown by haemoglobinuria and a deeply yellow coloured jaundice, and even, after some days, by an intense secondary anaemia.

Generally speaking this haemolytic action of aniline and aromatic amines is less marked and less lasting than that of the corresponding nitro derivatives. In particular the action of the former in causing chronic anaemia is a diminishing one.

The direct action of aniline, its homologues and their derivatives upon the nervous system shows itself first by a state of excitement followed by a paralysis of the central nervous system. At the onset of the condition, excitement occurs with acceleration of the respiration, followed by fatigue, inertia, loss of consciousness, and coma. The effect on the peripheral nervous system is shown by paraesthesias and hypoaesthesias, both sensitive and sensory. The increase of the blood pressure which is noticed at the commencement, and which moreover in serious cases is followed by a fall of pressure sufficient to cause collapse, may be interpreted as a vaso-motor disturbance.

The lowering of temperature, which is associated with the action on the central nervous system, explains the use of certain compounds of aniline, such as acetaniline and preparations of phentodine, as temperature reducers. But, on the other hand, it is probably this same phenomenon which causes delayed oxidation with partial internal asphyxia and brings about collapse.

In all serious cases secondary phenomena affecting the central nervous system are due to internal asphyxia (dyspnöea, profound coma, cramps, etc.), and are associated with symptoms arising from direct action on the nervous system.

Experiments on animals have made it possible to determine the fatal doses of aniline: 0.1 to 0.2 grm. per kilo for cats; 0.5 grm. per kilo for dogs; and 1 to 2 grm. per kilo for rabbits, which possess a fairly vigorous resistance to the formation of methaemoglobin. Calculating from a fatality caused by a dose of 25 grm. of aniline, Fr. Mueller estimated the fatal dose for man at 0.3 grm. per kilo; but the dose would actually be smaller when the aniline is completely absorbed.

The local irritant action of aniline has been studied experimentally on the cornea and conjunctivae of frogs. This action has been also reported among men employed in using aniline black in dye works. However, it probably should not be attributed to the aniline itself, but to products of oxidation which occur during dyeing and are very irritating. Cases of irritation of the mucous membrane of the respiratory organs by aniline fumes are not known.

As regards individual susceptibility it is generally accepted that women are more sensitive than men to acute poisoning. However, this only seems probable with regard to withstanding chronic anaemia induced by aniline and other aromatic amines. It has
also been suggested that resistance to the poisoning is less among thin people, or those of poor constitution, but that susceptibility is particularly increased in the early stages of infectious diseases. Numerous experiments have established the fact that even moderate consumption of alcohol may cause aniline poisoning to flare up suddenly among workmen who are employed on nitro or amido aromatic derivatives, and that habitual use of alcohol lowers resistance to this poison. These phenomena are probably explained by the rapid setting free of small quantities of poison accumulated in the fat of the body, where it remains inert until set free.

The action of aniline and other aromatic bases on the mucous membrane of the bladder and urinary tract is quite characteristic. It is shown in serious cases by irritation of the mucous membrane of the bladder, by strangury and later by haematuria. These facts were first described by Grandhomme in 1877, and then noticed in the experimental poisoning of animals by naphthylamine. The worker who passes some years in contact with aniline or other aromatic bases sometimes contracts a chronic irritation of the bladder, or even benign (papillomata) or malignant (carcinomata) tumours of the bladder. It has not yet been possible to decide whether this irritation and these tumours are caused by the bases themselves, eliminated as such, or by certain products of assimilation formed by the introduction into the molecule of one or several oxhydro groups: amido-phenols and amidonaphthols. This last supposition seems probable; however, a strong irritant action on the bladder found particularly in acute cases (Stark, Friedlaender) is attributed to paratoluidine, which is eliminated generally without undergoing any change. This has not been observed only with the primary amines (aniline and its homologues, benzidine, toluidine, alpha- and beta-naphthylamine), but it has also been noticed with dimethyl-aniline. Probably it arises with quite a number of aromatic bases.

The sulphonic acids of the amines, which, as a matter of fact, are only toxic in a slight degree, do not seem to have any effect on the bladder. Experience does not permit of the admission that aniline and benzidine, contaminated with aniline, are alone able to cause diseases of the bladder as suggested by Nassauer. As a matter of fact beta-naphthylamine, even when not contaminated by other aromatic bases, is one of the most formidable causes of tumours. Similarly the true cause of aniline tumours cannot be attributed to the presence of arsenical compounds as impurities in the finished article (A. Hamilton), for this hypothesis is in contradiction with the fact that diseases of the bladder have not been found among men who work with nitro-derivatives, naphthols and the sulphonic amines. Accumulated experience shows that tumours appear among workmen who have been exposed for a fairly long time to the poison — three years at least — and that at the same time prolonged even very small quantities is sufficient to cause the disease. There is no need for there to have been any previous attack of acute poisoning or any reaction to toxic absorption, for apparently such manifestations do not play any part in the outbreak of the disease. Naphthylamines, for instance, never cause symptoms of toxic absorption.

There is not sufficient proof that absorption of fumes alone, and then even in the weakest concentrations, may cause diseases of the bladder, as Nassauer suggests. However, continued exposure to aromatic bases, or to their vapours, seems sufficient to cause these diseases. As a matter of fact, most of the cases have been observed in places where the following conditions were realised: melting rooms in factories which manufacture dyes derived from tri-phenylmethane, autoclave rooms in the works for intermediate products, workplaces for the manufacture of sulphonic acids by the kiln process. It must be borne in mind that tumours of the bladder may sometimes appear several years after the cessation of work.

From the toxicological point of view, other homologues of aniline which have a technical importance, and its basic derivatives, in particular the alkylated and arylated amines, act in a manner quite analogous. They all easily form methaemoglobin and also possess the other properties of aniline: it is noted especially that they exercise the same action on the nervous system, which in some cases is even more marked. Data are not available as to the relative toxicity of toluidine isomers of nitro-anilines and of alkyl substituted amines. Toluidines cause in vitro a
much stronger formation of methaemoglobin than does aniline. Serious cases of poisoning, with blood-stained urine, have been noted, caused by splashes of toluidine on the skin. The meta-derivatives are the most poisonous, the ortho-derivatives the least. Experiments carried out on animals corroborate the following results: they act on the central nervous system, and produce cyanosis although less marked. The comparative effect on haemoglobin undergoing change.

Aniline, its homologues and basic derivatives are very easily absorbed by the skin, for they are excellent lipid solvents. The intact skin constitutes then a very important path of entrance for acute industrial poisoning. Experience has shown that in factories most of the serious acute poisonings occur when the workers have had their clothing (or skin on the occasion of accidents with the apparatus) soiled by aniline. Such occurrences may be considered as typical of aniline poisoning.

The possibility of absorption by this channel is again shown by casual accidents due either to wearing boots dyed black with aniline, or to rubbing the skin with aniline by mistake.

Lewis, it is the meta-which is the most toxic for animals. The para- is the compound which in practice causes the greatest number of poisoning cases, of dermatitis, and of conjunctivitis.

Among the nitro-anilines, para-nitraniline, an important body in technical processes, is the most poisonous and seems to be considerably more so than aniline. The fatal dose for dogs is 0.3 grm. per kilo for ortho-, and is certainly smaller for para-nitraniline. According to Lewis, it is the meta-which is the most toxic for animals. The para- is the compound which in practice causes the greatest number of poisoning cases, of dermatitis, and of conjunctivitis.

The toxicity of alkylated and arylated amines resembles almost that of aniline. As has been seen above, elimination of aniline is carried out chiefly by the urine under the form of par amidophenolsulphonic acid (NH₂—C₆H₄—O—SO₂H). Some traces are, however, eliminated by the urine without transformation (Fr. Mueller, von Engelhardt, Frank, and Beyer); and some quite considerable quantities, representing up to 1 per cent. of the dose absorbed in twenty-four hours, are eliminated by the breath (Rambousek). The introduction of a hydroxyl group into the para-position, in place of the amido group, and the partial elimination in the form of the corresponding para-amidophenolsulphonic acid, or in the form of glycoroninic acid, have also been observed, or presumed, with certain homologues and derivatives of aniline. Para- toluidine and para-nitraniline are eliminated for the most part without undergoing change. The formation of methaemoglobin by these bodies is probably due to a reversible hydroxylation of the nitrogen atom with the formation of phenyl-hydroxylamine.

**Sources of Danger**

Aniline, its homologues and basic derivatives are very easily absorbed by the skin, for they are excellent lipid solvents. The intact skin constitutes then a very important path of entrance for acute industrial poisoning. Experience has shown that in factories most of the serious acute poisonings occur when the workers have had their clothing (or skin on the occasion of accidents with the apparatus) soiled by aniline. Such occurrences may be considered as typical of aniline poisoning.

The possibility of absorption by this channel is again shown by casual accidents due either to wearing boots dyed black with aniline, or to rubbing the skin with aniline by mistake. Lehmann was the first to show, by his experience on animals, the possibility of aniline being absorbed by the intact skin and that it may rapidly bring on fatal poisoning. This ease of penetration through the skin, which is explained by the high lipoid solvent power of aniline, is also found among its homologues and with all aniline derivatives, which also dissolve fats and especially with the alkyl substituted anilines. The sulphonic acids do not, however, possess this property.

In the second place as a cause of industrial poisoning, the absorption of aniline in the form of vapour by the respiratory passages must be considered. This applies also to the homologues and derivatives which are sufficiently volatile, but not to sulphonic acids. According to the experiments of Lehmann, the vapour pressure, which at certain times can exhibit aniline, is sufficient when it gives strengths of 1.2 grm. at 20° C. and of 0.9 at 15° C. per litre of air.

In the immediate vicinity of apparatus air may momentarily show such high percentages of aniline. These quantities are due to the volatility of aniline and many of its derivatives at high temperatures. Aniline vapours are particularly liberated in the manufacture of dyes from tri-phenylmethane when the melted mass still hot is withdrawn from the furnace. The same dangers occur in the manufacture of sulphonic acids by the furnace process and by the autoclave process, when the apparatus is insufficiently airtight. Then, again, in a series of operations account must be taken of the ease with which the compound is carried over by steam.

According to Lehmann and his pupils, man and animals can remain without perceptible effects for a quarter of an hour to half an hour in an atmosphere containing 0.3 mg. of aniline per litre of air. Larger quantities absorbed during a longer time bring on serious or fatal results both in men or animals.
ANILINE

With cats 0.64 to 0.36 mg. of aniline per litre of air inhaled over 4 to 6 hours causes death in 7 to 12 hours after the absorption; 1 to 2 mg. of aniline per litre of air cause death as soon as two to three hours after exposure. The experiments of Lehmann also show that part of the aniline present in the air can be absorbed by the skin. It is probable that in practice absorption of aniline from the air is greater than that which corresponds to absorption by the respiratory passages alone; for, given a certain strength of aniline in the air, account must also be taken of absorption by the skin of aniline vapour which has condensed either on the skin or on the clothes.

Generally speaking, however, aniline vapours rarely give rise to serious acute poisoning when attention has been paid to precautions for preventing their escape into places where industrial operations are carried on which are liable to set free these vapours, either momentarily or continuously. Among these operations must be placed first handling and washing the melted mass during the manufacture of dyes from tri-phenylmethane, the use of aniline and its homologues in the autoclave or furnace processes (see above).

Danger from aniline vapour is very much greater during hot weather, and especially when the day is close and stuffy. At these times, when the work is over, numerous cases are observed of slight cyanosis and acute or chronic symptoms of aniline poisoning. These disorders are probably caused by disturbances in ventilation due to atmospheric conditions and by the sweat which increases the absorbing power of the skin.

The absorption of aniline and its homologues and derivatives by the mouth and respiratory passages does not play an important part in industrial poisoning.

Speaking generally, it may be said that the preparation of aniline and its homologues causes much less occupational poisoning than their use and the subsequent manipulation which they undergo. At the present time the preparation of aniline is carried out almost exclusively in hermetically-closed apparatus in large works provided with every technical improvement and hygienic arrangement that can be desired.

When work is normal the men cannot come in contact with the finished product, within closed apparatus whence pipes carry it into reservoirs, or tanks on wheels (wagon-s-citernes), or take it straight into workrooms where it is immediately subjected to fresh changes. Removal of the iron residue which forms in the reducing vessels and cleaning it off these vessels, as well as drying and further utilising the residue (for example, in the manufacture of sulphate of iron), do not present any danger. As a matter of fact, pure steam is used to sweep out the aniline at the end of the reduction; the residue is then free from all trace of aniline, as well as the water which has condensed in the apparatus.

In these factories workmen can only be contaminated with aniline when unexpected accidents occur or during repair work. As a general rule liberation of aniline vapour, or of steam containing aniline, during the reduction or during the transport of the product can be avoided by constructing suitable apparatus and, if necessary, by using exhaust draughts. The same remarks apply to the purification of raw aniline by distillation in vacuo.

Numerous cases of severe poisoning occur during the preparation of the derivatives of aniline and its homologues when open vessels, in which the manipulations are effected, are accidentally upset. Further, the formation of aniline vapour and steam containing aniline cannot be avoided in many of these operations as completely and certainly as during reduction. Among the processes giving rise to these dangers, may be specially mentioned the extraction of "Retour-oil", that is, distillation carried out in apparatus which is insufficiently closed; the preparation of aniline salt in a trough open or only covered with a wooden lid which is not airtight; gathering, crushing and drying the salt; drawing the furnace of the hot mass in the preparation of phenylmethane dyes and their transformation into sulphonic acid; the preparation in an autoclave of the alkylated and arylated derivatives. It is in these industries, so it seems, that tumours of the bladder have been most often noticed.

Aniline has also caused acute poisoning fairly often in the rubber industry, where it is used in the extraction of raw rubber and as an accelerator in vulcanising, as well as in aniline-black dyeing, where it is used in the form of aniline salt. Cases of aniline poisoning have also been notified in the manufacture of synthetic indigo, for phenylglycine always contains unconverted aniline. These cases, acute or chronic, occur most often in the filtering and drying departments, and
during transportation. There must also be borne in mind dangers due to nitrous fumes and chloracetic acid, which causes very painful burns and serious desquamation of the hands.

STATISTICS

It is not always possible to give complete statistics of cases of poisoning by aniline, for very often these cases are classed with those due to other substances, such as benzene and nitro- and amido-derivatives, or they are grouped under the general term of nitro- and amido-derivatives.

However, it is possible to give the following statistics:

Austria. — Several cases of eczema by para-nitraniline were reported in a workshop for printing textiles; two cases of poisoning by aniline oil in a linen factory were reported during the period 1914-1916; nothing is known of para-nitraniline poisoning during 1919 and 1920.

In 1921 a worker employed in grinding colours in a paper-works was affected by slight poisoning by aniline; in 1922, as a set-off to this, several cases were reported in an aniline factory due to leaky apparatus.

Germany. — According to the figures collected by Lehmann (1906) for the period 1896 to 1904, 1,161 workers employed in a factory for aniline, nitro-benzene and by-products showed 41 cases of diseases of the nervous system, 6 of the circulatory system, 141 of the respiratory passages, 35 of the digestive organs, 144 cases of infection, 221 cases of various kinds of disease; 35 of burns, 136 of other external lesions, 75 cases of diseases of the locomotor apparatus, 233 cases of diseases of the skin.

The same authority declares that one case of aniline poisoning was reported in 1886-1887, 3 in the following year, 42 from 1891 to 1896, 10 from 1897 to 1898, 65 from 1899 to 1900 (including, however, cases due to nitro- and dinitro-benzene), and 17 from 1901 to 1904. Reports of factory inspectors for 1913 refer to 8 cases of aniline poisoning in Prussia, and 8 in Bavaria, whence cases of poisoning from para-nitraniline and para-chloraniline are also announced. In the State of Baden cases of dermatitis and conjunctivitis, due to safranine in an aniline works, are also mentioned during the year 1913.

Inspectors were only aware from 1914 to 1918 of cases of tumour due to aniline and its homologues (see tumours caused by occupation). In 1919 cases of poisoning were notified in Prussia, one of which was caused by bromaniline; some slight cases have also been notified at Hanover in a rubber factory, due to aniline oil which may also have caused poisoning in a railway-carriage works, for aniline oil is the principal constituent in the red colour used for colouring wood. In Hesse 2 cases have been notified caused by para-nitraniline. In Bavaria 2 cases only have been reported caused by nitro- and amido-derivatives (see article "Tumours").

In 1920, of 17 cases of aniline poisoning reported in the Wiesbaden district, most were due to nitrochlorobenzene. In 1921 a dozen slight cases observed in a chemical products factory in the Saar likewise occurred, chiefly among workmen employed in the production of para-nitraniline; 29 cases were notified in Baden; most of these, however, except those in which the bladder was involved. In the following year 38 cases of aniline poisoning occurred in the same district, among the workmen of two factories; only caused by splashing of liquid chloraniline, had a fatal issue. Ten cases of dermatitis and eczema have been reported among workmen employed in aniline dyes and dinitrochlorobenzene. In Bavaria several cases of dermatitis have also been notified caused by safranine, violanthene, and chlorbenzanthrene. This last also shows a pronounced sensibility to light. In 1922 some 117 cases were due to para-nitraniline were reported.

Great Britain. — The reports of the Chief Medical Inspector of Factories mention 18 cases of poisoning by nitro- and amido-derivatives in 1910 (aniline poisoning, 1; dermatitis, due particularly to dinitrochlorobenzene, 17); 21 in 1911 (aniline poisoning, 18; dermatitis due to dinitrochlorobenzene, 3); 9 in 1912 (aniline poisoning, 4, of which 1 was fatal; dermatitis, 5); 8 in 1913; 38 in 1914 (aniline poisoning, 32, of which 2 were fatal; dermatitis, 6); 4 (2 of which were fatal) in 1917; 7 in 1918 (of which 4 were fatal). In 1919 1 case of a worker suffering from aniline poisoning was reported. An enquiry made in 1921 by Dr. Henry in 23 dyeworks using aniline black, where there is double risk from aniline dyes and dinitrochlorobenzene, from chrome ulcerations, emphasises the fact that, from the hygienic point of view, the most important operation is that of "ageing", which precedes chroming. The exact chemical reactions which take place in the ageing chamber, or ager, in the oxidising process are not known, but it is certain that there is a liberation of aniline fumes. Further, chlorine may be formed. In the same way in the steam process, the chemical reactions are very complex and it is very difficult to avoid the liberation of steam which carries with it aniline vapour.

In addition, the ager has to be periodically cleaned.

A clinical examination undertaken by Dr. Williamson of 39 aniline black dyers and 3 aniline makers, enabled him to report a distinct diminution in the percentage of haemoglobin, or in the number of red cells. There was also a diminution in the white cells, with a relative increase of the lymphocytes. The examination showed further a lower colour index, and an alteration, in certain cases, in the blood pigment. These changes, but more marked, were observed in the urine of the aniline makers. Signs of slight absorption were noticed by Dr. Henry in 17 workers
and more serious in 14 making 46 per cent. of those examined; pallor in 31 cases; anaemia was noted in 14, or 21 per cent.; cyanosis in 12, or 18 per cent.; and tremor in 6, or 9 per cent. In some cases the workers complained of headaches, vertigo, and loss of appetite. As regards the frequency of symptoms, according to processes, the following returns were made: dry agers, 83.3 per cent.; impregnators, 68.6 per cent.; mixers, 40 per cent.; dryers, 40 per cent.; steam agers, 20 per cent.; skin dyers, 10 per cent. In this same year 4 cases are mentioned as affecting three workers and a chemist employed in sieving para-nitraniline.

In 1924, 24 cases of aniline poisoning were notified, and in 1925 (the first year of compulsory notification of cases of aniline poisoning) 31 cases.

Prosser White reports that in a factory for weaving coloured cloth about 30 persons were affected with serious eruptions accompanied by itching of the face, neck and hands (the interdigital spaces), etc., due probably to indigo blue.

Netherlands. — In 1914 a case of aniline poisoning was notified in a brush factory. It was attributed to handling vegetable fibres dyed with aniline. In 1916, two cases were reported by the factory inspectorate, of which one was a chemist and the other a weaver; two cases were also notified in 1917, one of which was a workman employed at an aniline boiler and the other in weaving, where the work consisted in using aniline as a mordant. In 1919 two cases of aniline poisoning were reported, and in 1920 one case affecting a negro employed as a laboratory boy, who had upset twenty litres of aniline oil and, although warned of the danger, had not taken the precaution of changing his soiled clothes after having cleaned the place where the aniline was upset.

Switzerland. — The cases of poisoning by aniline and other aromatic bases numbered 2 in 1911, 8 in 1912, and 2 in 1917; 5 cases of aniline poisoning and 1 case of para-nitraniline poisoning in 1919; 7 in 1920; 2 of aniline poisoning and 1 of dermatitis in 1921; 8 cases of chronic aniline poisoning in 1922; 3 acute, 5 chronic and 6 cases of dermatitis in 1923; 5 acute, 7 chronic, and 5 of dermatitis in 1924; 10 chronic cases and 6 cases of dermatitis in 1925.

United States. — In the State of Ohio, prior to the Act of 4 August 1921, 71 cases of aniline poisoning were known; from 1 July 1920 to 30 June 1925, 33 cases were notified; 11 cases had been caused by para-nitraniline, 3 by paratoluidine, and 1 by xylidine. In the State of New Jersey, 23 cases of aniline poisoning were notified in 1917 and 23 in 1920.

A doctor attached to a factory where the workmen manipulate great quantities of diethyl-aniline treated several cases of poisoning by this substance which caused the same symptoms as aniline. A case caused by meta-nitraniline is reported by Hamilton. It concerned a workman who had been cleaning an apparatus which contained meta-nitraniline. The chief symptoms were vomiting, headaches, pronounced cyanosis, and loss of consciousness. Another case is reported in the returns of the Labour Department of New York.

Cases of poisoning by ortho- and para-toluidine seem to be fairly frequent (Hamilton), but more precise figures are not available. Hamilton mentions also 2 cases of serious poisoning by 'dimethyl-aniline observed in 1916 in a dyeworks where the workers came in contact, one with liquid aniline and the other with fumes of aniline coming from a vat full of violet dye prepared from dimethyl-aniline, phenol, and other substances.

**Symptoms**

**Acute Poisoning**

The clinical picture of acute aniline poisoning is characterised by the action of aniline and its derivatives on the blood and particularly on the haemoglobin. The earliest symptom — which is often noticed before the actual appearance of subjective disorders accompanying the poisoning — is pronounced cyanosis, which is known by a bluish-grey colouration of the skin, which at the onset is particularly noticeable at the extremity of the nose, ears, cheeks, and nails. It is distinguished from cyanosis due to lack of oxygen, especially in an advanced stage, by a more marked bluish-grey produced by the transformation of haemoglobin into methaemoglobin which makes the blood of a brownish colour.

As regards the nervous system, a state of slight excitement, analogous to drunkenness, first appears, combined with a certain feeling of physical fitness, which gives a false sensation of wellbeing. These are the only symptoms observed in slight cases of aniline poisoning, and they disappear completely in a few hours or in a night. In serious cases the cyanosis increases rapidly. The diffuse dark bluish-grey colour of the skin and particularly of the mucous membranes, makes a great impression on persons who are not used to these symptoms and contrasts, at this period, with the absence of other symptoms characteristic of serious poisoning. The blood takes a brown colour and may even become black as tar.

Instead of the symptoms of excitement observed at the onset in the case of the nervous system, signs of paralysis are noticed at this phase of the poisoning: fatigue, somnolence, weakness, vertigo, sometimes with vomiting and headache. Paraesthesias — a sensation of numb-
ness in the extremities — singing in the ears, and dimming of the field of vision are also observed. The follow-
total loss of consciousness and coma, together with contraction, and then dilatation and paralysis of the reaction of the pupils. At this stage are also noticed symptoms of internal asphyxia, a sign of progressive formation of methaemoglobin: dyspnœa, then slow and irregular respiration and cramps.

According to the statements of some writers, the blood pressure is increased at the beginning, the action of the heart is stronger and quickened, then, in the place of vaso-motor excitement, paralysis appears accompanied by the following symptoms: diminution of the blood pressure, feeble pulse, moist and cold skin, collapse. In serious cases the temperature of the body is greatly and rapidly diminished. Next is observed, especially in fatal cases, a very low temperature characteristic of collapse.

In acute poisoning death takes place during profound coma; it is caused by central paralysis accompanied sometimes by cramp and dyspnœa. In non-fatal cases recovery is often very rapid, even when the symptoms have been very severe. Notably cyanosis with methaemoglobin disappears very rapidly and completely — often during the first twenty-four hours in slight poisonings, and in a few days in the serious cases. This disappearance is much more rapid than in poisoning by nitro-derivatives of the aromatic series, probably because aniline becomes changed more quickly into hydroxylated products capable of being eliminated by the urine. In slight cases the disappearance of the methaemoglobin takes place rapidly and brings about a complete cure. In serious cases, quite often in the first days of the poisoning, strangury occurs and the urine is slightly blood-stained. The urine is dark, brownish (approaching green); it becomes much darker when its alkalinity is increased and then resembles carabolic urine.

In serious poisoning, even when not accompanied by haematuria, not only does the urine contain haemoglobin and methaemoglobin, which can be detected either chemically or spectroscopically, or yet by the microscope in the form of drops of Boström, but there is present a yellow colouring material derived from the decomposition of red blood cells. In a few days the number of these cells diminishes considerably. Secondary anaemia shows itself; it is accompanied by a diminution of the colour index and a regeneration of the red blood cells with formation of normal cells or giant cells with nuclei. The jaundice is slight and momentary: it is less pronounced and less frequent than in poisoning by the aromatic nitro-derivatives. Complete recovery may be much retarded by the secondary anaemia.

Chronic poisoning by aniline is caused by prolonged absorption of small quantities of poison and is generally due to the accumulation of the haemolytic effects of aniline. In addition to this action a chronic action of aniline on the nervous system may also be noticed, chiefly characterised by a slight secondary anaemia. The colour index of the blood and the number of red cells are diminished; microscopical examination, however, rarely shows regenerative changes, that is to say, no indications are found of a return to an embryonic state of erythropoiesis. But it is possible to find young red blood cells containing colourable granulo-flamentous substance, fresh or as a polychromatic substance (dry colouring) (Biondi). In the same way, contrary to what occurs in chronic occupational aniline poisoning where benzene and dinitrobenzenes are handled, jaundice is almost always absent. Cyanosis does not come into the clinical picture of this chronic poisoning by aniline and is only seen momentarily as long as the worker continues at work. Curschmann also mentions as a symptom of chronic aniline poisoning an increase in blood pressure. Among the troubles caused by the secondary anaemia, subjective symptoms must be noticed, such as loss of appetite, digestive troubles, feeling of weakness and fatigue, tendency to giddiness and headaches, and, in serious cases, disorders of locomotion and of sensation.

Diseases of the bladder, which have been mentioned above, are a late sequela of prolonged contact, over several years, of the worker with aniline or other aromatic bases. They may appear several years after cessation of work, and in three distinct forms; these forms, however, only constitute different stages of the affection of the bladder, which terminate by degenerating into malignancy. These three stages are as follows: (1) simple recurring haemorrhagic cystitis; (2) benign papilloma, which is often a multiple papillomatous condition of the bladder; (3) malignant tumours of the bladder (carcinoma).

Haemorrhagic cystitis which is frequently the cause of severe haemor-

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blood through the mucous membrane of the bladder, with formation of haemorrhage, for varying as to size from that of a pin's head to that of a coin. They are localised to the region of the openings of the ureters and the trigone. Cure may be quite rapid. Papillomata also are situated as a rule in the vicinity of the trigone. They show a very strong tendency to recur. Malignant tumours of the bladder, which have no particular localisation, are fairly often the sequelae of recurrent papillomata; but they may be primary tumours. Up to the present the formation of tumours in the upper urinary tract (the calyces and ureters) has only been rarely noted. Recurrent papillomata; but they may show a very strong tendency to recur. Papillomata also are situated as a rule of the openings of the ureters and the bladder, haemorrhagic foci varying as to size from that of a pin's head to that of a coin. Symptoms typical of aniline poisoning. By Jacquemin, Letherby, Cromer, and Gautier, or Maquenne, containing 10 c.c. of distilled water, or, better, of a weak solution of sulphuric acid. A volume of 10 litres or less of air should be drawn through.

For qualitative analysis the liquid from the absorption tube is poured into a small distilling apparatus and water from washing the same, absorbent tube is added. If acidulated water has been used, it must be rendered alkaline by adding some drops of potash or soda lye. The alkali sets aniline free from its combination with sulphuric acid. After distillation about 1 c.c. of the liquid is collected, which includes almost all the aniline contained in the retort. The small volume of liquid obtained is submitted to qualitative tests.

Among the different reactions proposed by Jacquemin, Letherby, Cromer, and others, the most practical for use in industrial hygiene seems to be that of chloride of lime. This consists in adding to the liquid for analysis some drops of an aqueous concentrated, and fresh solution of chloride of lime. A violet coloration is obtained more or less deep according to the proportion of aniline.

For quantitative analysis it is an advantage to estimate the aniline vapours, if they are in any considerable quantity, in the air by the method of weighing. Hebert and Heim de Basil have employed the following method: fix the aniline in an absorbing tube by a weak solution of sulphuric acid (0 per cent. empty into a beaker and add the washing water; estimate the aniline in the fixing liquid by bromine water which precipitates it in the form of bromobenzidine which is almost insoluble (1 part in 69,000 parts of water); collect the precipitate on a weighed filter paper; weigh again after cold drying under a bell jar, which a vacuum is maintained, in order to avoid decomposition by heat. The weight of tribromaniline obtained allows the weight of aniline, from which the tribromaniline has been derived, to be calculated, knowing that 1 part of tribromaniline corresponds to 0.28 parts of aniline by weight. Toluidines also give a precipitate with bromine water; but this precipitate is comparatively soluble (1 part in 6,450 parts of water), so no considerable error in the results follows, the more so since the proportion of toluidine in the air of workshops is always small.

In the urine. — Paramidophenol is easily detected in the urine by saponifying sulphuric acid which has been combined by heating with dilute hydrochloric acid. To obtain this, the urine is acidulated with hydrochloric acid and chloride of iron are added, and then ammonia; this produces a deep blue coloration. It can also be diazotised while cold by means of nitric acid and coupled with alpha-naphthol in weak sodium solution; the reaction produces a dark red coloration.

Search for paramidophenol in urine can also be easily made by using nitric colour reactions.

Detection of aniline in organic materials is carried out by various methods. According to that of Oliver and Bargeron, the materials to be analysed are heated with sulphuric and arsenic acids; in this way aniline is transformed into fuchsin (sulphate of rosiniline). The residue is treated with alcohol, precipitated by acetate of lead, filtered, the excess of acetate of lead is eliminated by the addition of dissolved sulphate of sodium and filtered again; the solution is then rendered alkaline by potash and distilled in an oil bath; the distilled product contains free aniline, which is transformed into sulphate. Searches delicate reactions enable the sulphate to be distinguished.

It must, however, be borne in mind that commercial aniline is almost always mixed with the higher homologous products (toluidines) the presence of which modifies the colour reactions of the aniline itself.

**ANILINE**

**DETECTION**

**In the air.** — Fixation of aniline vapours is easily obtained by passing air, at the rate of 1-2 bubbles a second, through an absorption tube of the pattern of Liebig, or Gautier, or Maquenne, containing 10 c.c. of distilled water, or, better, of a weak solution of sulphuric acid. A volume of 10 litres or less of air should be drawn through.

For qualitative analysis the liquid from the absorption tube is poured into a small distilling apparatus and water from washing the same, absorbent tube is added. If acidulated water has been used, it must be rendered alkaline by adding some drops of potash or soda lye. The alkali sets aniline free from its combination with sulphuric acid. After distillation about 1 c.c. of the liquid is collected, which includes almost all the aniline contained in the retort. The small volume of liquid obtained is submitted to qualitative tests.

Among the different reactions proposed by Jacquemin, Letherby, Cromer, and others, the most practical for use in industrial hygiene seems to be that of chloride of lime. This consists in adding to the liquid for analysis some drops of an aqueous concentrated, and fresh solution of chloride of lime. A violet coloration is obtained more or less deep according to the proportion of aniline.

For quantitative analysis it is an advantage to estimate the aniline vapours, if
HYGIENE

The most important point in preventing ill-effects from aniline and its homologues lies in the construction of apparatus and the use of adequate procedures of manufacture. By reason of the facility with which these substances penetrate the intact skin and are absorbed by inhalation it is necessary to avoid, as far as possible, all contact with the raw materials, as well as the liberation of aniline vapour or of steam containing aniline. Hermetically-closed apparatus must therefore be used, and transport of the liquids must be effected through closed channels. Whenever possible transfer from one vessel to another should be effected by the aid of compressed air or by vacuum. Liberation of vapours containing aniline should be avoided by condensing, or absorbing them, or evacuating them by exhaust draught. This elimination should be done at the actual place where the vapours are formed, for instance, at the outlet of the furnaces in the preparation of triphenylmethane.

In the same way all vats, receptacles, or other open apparatus used in the industry of dyestuffs must be supplied with covers.

Natural change of air in the workshops must be assured as far as possible by suitable construction of the building and by well-arranged windows and skylights. Artificial ventilation may even be required.

It is indispensable that floors be kept clean, especially in factories where aniline is converted and prepare by-products. As a matter of fact, the handling of liquid by-products, and particularly of solid products (breaking up) in the vats for reducing and grinding, is a cause of uncleanliness. The floor must not be of asphalt or tarred, for it would then absorb aniline and other aromatic amines.

Personal prophylaxis is also very important. Working clothes should be changed often and regularly. Cleanliness must be scrupulously attended to; baths must be taken at regular intervals. Workers must be warned of the poisonous nature of the substance handled, of the danger arising from dirty clothing and the necessity of immediately changing clothes which are too soiled, and of the special risks which attend the taking of alcohol. It is of the greatest importance to exercise regular medical supervision so as to keep oxygen in reserve for treating cases of poisoning as quickly as possible (see below, "Legislation").

In order to prevent diseases of the bladder a very rapid change-round of workers has been prescribed and regular analyses of urine, so as to discover haemorrhages early. This last measure is not really of great prophylactic interest, but it makes it possible for the worker who is already ill to receive surgical treatment as early as possible.

LEGISLATION

As regards the work of women and young persons see articles Chemical Trades, Benzene, Nitrobenzene, Trinitrotoluene, etc.

Medical examination on engagement is provided for by British and German legislation (during the first fortnight following engagement) and periodical monthly examination is laid down in Great Britain and Germany.

A circular of the Minister of Commerce and Industry of Prussia, dated 21 October 1911, on the setting up and working of the manufacture of nitro- and amido-compounds contains some very interesting measures, applicable also to factories which make other reactive benzols, toluols, xylols, nitrated once or several times, and their chlorine compounds, the naphthalenes nitrated once or several times, the phenols and naphthols nitrated once or several times, aniline and its homologues (toluidine, xyline, cumidine), anisidine, phenetidine and their compounds with chlorine, nitre, alkyl and aryl, phenylendiamine, tolylen diamine, benzidine, diaminidine, phenylhydrizane, etc., the manufacture of fuchsin, blues and blacks, etc.

The workplaces must be lofty, very airy and capacious. Buildings arranged in floors are not recommended; the construction of platforms is admissible provided there is a free space of at least three metres between them, and that there is reserved between these platforms and the walls a free space of from 50 cm. to a metre. No platform must be situated above melting boilers or distilling apparatus, except where there are special appliances for preventing the liberation of gas or vapour.

The floor must be impermeable, well levelled, easy to clean with a suitable slope to a drain channel. Floors made of stone flags, or tiles set in cement, are very good and easy to keep in order, but the tiles should not have any deep grooves. Concrete has not always given satisfactory results; above all it must not be porous and must present a smooth surface. It is affected by acids and hot liquids. Factories which work with acids use flags of sandstone impregnated with tar and fill up the joints with asphalt. This type of floor offers very great resistance to acids, but it is not suitable for departments of nitro- and amido-compounds, for they combine with tar and asphalt.

The walls must be covered, with a
wastable coating or whitewashed. In that case the whitewashing must be done once a year.

If compounds of the benzene or napthalene series, nitrated two or three times, are produced in the factory, the building must be constructed of incombustible materials, for in case of fire, sudden decomposition of highly nitrated compounds may occur.

The operations should be controlled and the work managed in such a way that the workmen come in contact as little as possible with nitro- and amido-compounds. When they are in liquid form, they should as far as possible be conveyed in closed channels (by means of pumps, extractors or compressors); if they are in a soluble form, or in form of dust, they should be transported, poured from one vessel to another, or drawn off by means of mechanical apparatus or exhaust.

Aqueous solutions of phenylendiamine and toluyldiamine are also both very toxic, and dilute solutions may act on the skin. Hence the same precautions must be taken for these solutions as for the products themselves.

Air used for compression, as well as for exhaust, always contains a little aniline in the form of liquid (droplets) or vapour; for this reason this air should be conducted above the roof, and, if possible, purified to avoid any risk for the neighbourhood.

Liquid or solid compounds must be kept in closed receptacles (liquids) or covered containers (solids).

Operations which liberate vapours, dust or gas, and in particular those of crushing, sifting and packing, must, if possible, be done in a closed apparatus with localised exhaust. The receptacles used for collecting distillation products must be kept constantly closed. In order to avoid blocking, the pipes must be surrounded with a steam jacket or heated in some other way.

Evacuation should be so provided as to avoid any danger of vapours escaping at the moment of opening, or drawing, or filling (compression), drying chambers, melting boilers, autoclaves, and other receptacles under compression.

Solid products, melting at a temperature which is not very high, should be collected by distillation, etc., in closed receptacles connected to an exhaust apparatus and heated by steam. On passing out of these receptacles, they are poured while in the liquid state into small moulds, or on to cooled cylinders. Special arrangements should prevent the escape of vapours during these operations. But the withdrawal of cooled materials from the receptacles where they have been collected is always dangerous. Drying must be done in hermetically-closed apparatus with efficient exhaust draught.

Experience has shown that it is advisable to use over again the compressed air, which is charged with dust or gas, in such a way that it forms a closed circuit, and thus avoid having to purify it specially.

Dryers must be emptied after complete cooling, and during the emptying exhaust draught must be in constant use.

Absolute cleanliness of workplaces must be preserved, and traces of products upset or scattered about. Nitro- and amido-products should be taken up by sprinkling with sawdust, which is then swept up. It is best to burn the sawdust in small quantities. Substances in the form of dust can be advantageously taken up by aspiration by means of vacuum abstractors.

Workers should be taught the danger to which their work exposes them; and reminded that immoderate use of alcohol is always very dangerous even outside working hours.

Provision for personal hygiene is needed, as for all unhealthy industries, such as provision of overalls, footwear, lavatories, douche, baths, cloakrooms, etc. Overalls, shoes, or glides impregnated with nitro- or amido-compounds, or soiled in such a manner that the skin is in direct contact with these compounds, must be immediately removed.

Repairs of receptacles, pipes, etc., must only be done after thorough cleaning. Every possible precaution must be taken to avoid poisoning, which is too often fatal, by nitro- or amido-compounds, carbides of hydrogen, gases or vapours of these compounds, or by acid and ammoniacal gases or fumes.

The work should always be carried out under the constant supervision of a responsible person, instructed in his duties and not engaged in the actual work. After having removed, if possible, the covers and stirring appliances, the apparatus, before anyone enters it, should be subjected to boiling, or filled with water, or freed from all noxious gases by blowing air through or by exhaust draught. If these precautions cannot be carried out, the workers should be supplied with respiratory apparatus, and care should be taken that the air sent into the helmet is fresh and is delivered in a regular manner.

If it is not possible to open the covers, or if it is only possible to open them partly, the workers should have a rope attached to them; they must not remain in the apparatus more than ten consecutive minutes the first time, and they should only re-enter after a rest of at least an equal period. Pure air should be constantly blown in during the stay of the worker in the apparatus. After finishing work, the worker should take a bath or a douche, and change his clothes and shoes.

In Great Britain the second part of Regulations No. 731, dated 11 July 1922, relating to the manufacture of chemical products, applies also to factories or parts of factories in which work on nitro- or amido-compounds is done. It provides means for avoiding, as far as possible, liberation of dust or of vapours during the crushing of crystalline substances, or the stirring of solutions by hand; the installation of drying chambers provided
with brisk ventilation; the entrance of workers into drying chambers only after a current of fresh air has been introduced. Every receptacle in which nitro- or amido-derivatives, benzene or phenol, or their homologues are subjected to the action of steam must be closed, the object being to prevent the escape of steam or vapours into any workroom; efficient exhaust draught is required for dust or vapour, as well as during grinding, crushing or mixing, etc., of nitro- or amido-compounds. These operations ought to be done in separate places where the floor must be of cement or other smooth impermeable and incombustible material, which must be cleaned daily.

The Regulations further provide for placing at the disposal of workers, and keeping in repair, overalls or suitable and sufficient working clothes and suitable boots. The clothes must be washed, cleaned, or renewed at least once a week. Persons for whom overalls or working garments must be provided shall have the use of a suitable cloakroom and a mess-room separate from the cloakroom, which shall be in the charge of a responsible person. These installations must be kept in a clean condition, well aired, and heated in cold weather. Further, these workers shall have at their disposal lavatories with soap and nail brushes, and an installation of douche or other baths, with hot and tepid water, soap, and towels in sufficient quantity. A bath register must be kept, where the date on which each person takes his bath must be recorded.

Poisoning by aniline and its homologues is compulsorily notifiable in France, Great Britain, the Netherlands, and Russia, and compensation is provided in Finland, Western Australia, British Columbia, Great Britain, and Switzerland. But it must be noted that compensation and notification are in certain countries laid down under the heading of "nitro- and amido-derivatives of benzene and homologues"; it is so as regards notification in Bavaria, France, Russia, and the Netherlands, and as regards compensation in Germany, Western Australia, British Columbia, Great Britain, the States of Minnesota, New York and Ohio, and Switzerland, Finland and Queensland.

**BIBLIOGRAPHY**

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(Berlin).

### Anisidines

These organic bases [formula, \( \text{C}_6\text{H}_4\text{NO}_2\text{H} \) (NH₂) (OCH₃)], derivatives of metallic ethers, of the nitrophenols or nitroanisols (see article "Phenols"), have three isomers, of which the ortho and para, and their salts, are used in making artificial colours.

Among the derivatives of the anisidines mention should be made of the *nitro-anisidines* [formula, \( \text{C}_6\text{H}_4\text{NO}_2\text{H} \) (NH₂) (OCH₃)], obtained by nitrating acetyl-anisidine. They are solid substances of which the para product is used in textile printing, the preparation of reds and pinks on beta naphthol.

Dianisidine is obtained by a process analogous to that employed in the preparation of benzidine (see that article), but starting with nitro-anisol (ortho). It occurs in the form of violet crystals (in the air), insoluble in water. The hydrochloride, soluble, on the contrary, in water, is used to prepareazo colours. The dianisidines are to-day very largely used in the preparation of direct dyes for cotton.

Dianisidine, which is a dioxymethyl benzidine, has an action analogous to that of benzidine (see that article).

Lauenberger classes this substance among those that can produce tumours of the bladder in aniline workers (see article "Aniline").

Dianisidine figures in the Swiss list of substances for which compensation as for an accident can be claimed.

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**Ankylostomiasis or Hookworm Disease**


The presence of the ankylostoma in the human intestine is described as ankylostomiasis. The infection due to this parasite ought rather to be described as "ankylostom-anaemia", but it is known under the most varied terms in different countries; the anaemia or chlorosis of Egypt, miners' anaemia, brickmakers' anaemia, etc. (see also p. 134: DANGERS AND STATISTICS). The term "uncinariasis" is also often used.

**THE PATHOGENIC AGENT**

There are two kinds of ankylostoma: *A. duodenale*, or European, and *A. Americanum* or *Uncinaria Americana* or *Necator Americanus* — both of them being nematoda of the genus *Strongylidae*.

Among the different species of *Necator* the following should be remembered: *N. Americanus*, originating from the gorilla and spread over tropical and sub-tropical regions; *N. caecidens*, a parasite of the chimpanzee (Africa); *N. Congoensis*, also a
parasite of the chimpanzee (Belgian Congo); and *N. suisius*, parasitic in the pig (Island of Trinidad, where the infected pigs vary from 60 to 100 per cent., with a quite special symptomatology). Curiously enough, experiments made to infect the pigs with *N. Americanus* have so far proved negative. *A. duodenale*, discovered in 1838 by Dubini, and studied especially by Perroncito and Raillet, is a pale flesh-coloured red worm, cylindrical, sexual; the male measures 8·10 mm. in length and 0·46 mm. in breadth, the female respectively 10·16 mm. and 0·95 mm.

The mouth, a real cupping glass with a chitinous armature, has two pairs of curved hook-like teeth on the ventral aspect and two small dorsal teeth which are the rounded edges of the "dorsal gap" of the chitinous capsule. The canals of two cephalic glands open into the buccal cavity. The oesophagus dilates into a muscular stomach and ends in a lateral anal orifice. The vulva is situated at the posterior third while the seminiferous tubules end in two spicules. This unusual arrangement explains the Y form assumed by the worms during copulation, the short end of the Y being represented by the male.

In the small intestine of its host the adult female lays her eggs, which scarce develop at all in the intestinal canal owing to lack of oxygen and do not develop until they have been expelled with the faeces and so reach appropriate surroundings (heat, humidity, relative darkness).

The two kinds of *ankylostoma* have the same life history, cause the same pathological troubles, and differ only in certain morphological characteristics, of which the most important are the following: the head of *uncinaria* is narrower than that of *ankylostoma* and is always bent dorsally. The buccal capsule is smaller. While *ankylostoma* shows two pairs of strong teeth curved downwards, *uncinaria* has only two cutting chitinous plates terminating in two large spines pointing towards the cephalic apex and a conical tooth projecting from the bottom of the buccal capsule towards the dorsal side far into the lumen. The bursa copulatrix opening is larger than in *ankylostoma* and the sides are of a more sober colour; the vulval opening in the female is in the middle of the body, while in *ankylostoma* it is at the posterior third. (For eva, see Diagnosis, p. 140.)

The complete cycle of the *ankylostoma* comprises, as in the case of all nematoda, three main or stages. During the 24 hours following its arrival in suitable surroundings, the ovum undergoes segmentation and develops, more or less rapidly according to the temperature, into an embryo or larva which pierces the shell of the egg, and escapes in the form of a rhabditiform larva (bulba oesophagus) (measuring 250 microns). After three days the first moult (larva of 300 microns) occurs and two days later the larva, which measures 480 microns, loses its oesophageal bulb and assumes the strongyloid or filiform appearance. In the second phase the strongyloid larva, measuring 560 microns, undergoes the second moult, in which a cyst is formed around the larva. It finds itself then protected and more able to resist forces in its surroundings likely to injure it. This is the stage at which it is ready to enter man. The *ankylostoma* cannot attach itself or develop in man except when in the larval condition. At this third stage the larva has not yet acquired a buccal capsule; after five days comes the third moult. Then follows the fourth phase: the larva has a provisional buccal capsule and on the fourteenth day occurs the fourth moult. In the fifth and last phase the larva has a definite buccal capsule, and in 21-28 days the adult form is reached with coupling of the two sexes and reproduction of the cycle.

The cycle can be sketched as follows: Human infection — contagion of the surrounding favourable ground — infection of the ground — man — human infection.

1 According to Wilson G. Smillie, who based his data on the studies of Clayton Lane, the microscopic differentiation between the two parasites can be made from the following characteristics:

**Ankylostoma duodenale**

*Female*

- **Length:** a little longer than *Necator* and much larger.
- **Form:** assumes always a position reminiscent of the letter "C" more or less accentuated.
- **Posterior extremity:** ends in a large and blunt point.
- **Colour:** white, sometimes a black spot near the oesophagus. Very frequently the fresh blood can be seen through the body of the worm.
- **Resistance:** analogous to that of cartilage (under a dissecting needle).

**Additional characteristics:** apply also to the male, for which, however, the following additional characteristics must also be borne in mind:

**Ankylostoma duodenale**

*Male*

- **Length:** longer than *Necator*; diagnosis can generally be made on this point alone.
- **Form:** very like a nail; sometimes slightly curved like the letter "C".
- **Posterior extremity:** terminates in an open fan-shaped bursa.

**Necator Americanus**

*Female*

- **Length:** rather shorter and thinner than *A. duodenale*.
- **Form:** assumes the form of an "S".
- **Colour:** white, sometimes a black spot near the oesophagus. Very frequently the fresh blood can be seen through the body of the worm.
- **Resistance:** analogous to that of cartilage (under a dissecting needle).

**Additional characteristics:**

*Male*

- **Length:** much smaller than *A. duodenale*.
- **Form:** always in the form of an "S" with the characteristic dorsal curvature at the cephalic extremity.
- **Colour:** white, sometimes a black spot near the oesophagus. Very frequently the fresh blood can be seen through the body of the worm.

**Pathological characteristics:**

- **Marked brownish colour; the red colour of the blood is hardly ever visible through the body.**
- **Soft worm (under dissecting needle).**
- **Always in the form of an "S" with the characteristic dorsal curvature at the cephalic extremity.**
- **Terminates in a closed bursa like the bud of a flower.**
From the arrival of the ovum outside the organism to the laying of eggs by the females in the human intestine, the cycle lasts from 45 to 56 days, i.e. 5-7 days outside the body and the rest inside.

The ova are killed by a temperature of 5° C., but show prolonged resistance to chemical agents. They do not develop in water, a temperature of 18° C. being needed. The temperature most favourable to their development is 25-30° C. The larvae also show considerable powers of resistance. Ova and larvae are easily killed by the sun, dryness, or frost; on the other hand, chemical disinfectants have only slight action in the conditions under which it is practical to apply them. Formalin notably is without action (see further under PROPHYLAXIS, p. 141).

In the organism the larvae resist the action of the gastric juice.

The larvae are reported to be able to migrate vertically in the ground; under certain conditions they come to the surface even if they have been buried with infected faeces at a depth of 90 cm. to 1 metre. Transmission of the larvae is not effected solely by the earth, mud, water, etc., but also indirectly by insects, flies, etc., which are said to be, however, only intermediate and purely accidental hosts acting as simple agents of transmission (Italy, Japan). The pig is also said to be the intermediate host for the dissemination of ova of ankylostoma (Trinidad), but apparently of a distinct species, the Necator suis (Rockefeller Commission Enquiry, John Hopkins University, 1922). Having reached the skin, the larva throws off its cyst and penetrates as far as the lymphatic spaces along the sheaths of the hair follicles, even if the skin is intact, but more easily if this is broken. The irritation set up by the larva favours its penetration. In 30 to 40 minutes the larva penetrates the skin and reaches the bloodstream. By way of the veins it passes into the right side of the heart and so passing through the pulmonary circulation it arrives at the alveoli; it ascends the respiratory tract as far as the trachea and descends from there along the oesophagus to the alimentary canal. Probably associated with this route, sufficiently complicated but definitely proved, there is another shorter and surer path followed by the larva from the skin to the small intestine where it attaches itself.

At all events, during this transit, the larva develops very little; it
arrives at sexual maturity only when it reaches the intestine, where the cycle recommences.

The parasites in the human intestine can number several thousands (from 4,000 to 6,000; apparently 2,000 is the average figure in warm countries). Some writers, Italian especially, assert, however, that they have not found more than an average of 200 and even numbers considerably less (from 12 to 14).

The life of the adult parasite in the intestine is limited: if new infections do not occur the ova cannot develop in the digestive tract and the worm dies (spontaneous cure).

DANGERS AND STATISTICS

The problem is a world-wide one — the menace of an obstacle to civilisation which demands international measures and efforts. The infection is confined in the earth over a range of 66 degrees of latitude (from 36° north to 36° south) inhabited by 940,000,000 persons exposed to risk (58 per cent. of the world's population), of whom at least 20 millions are infected. It should be remembered that the ankylostoma has been found at 57° latitude north (in Scotland), which proves that the danger is even greater than is generally conceded.

The Rockefeller Sanitary Commission to Combat Ankylostomiasis, organised in October 1909 (with its headquarters in Washington), proposed to determine geographical distribution of the disease, to undertake the treatment of the affected, to eliminate the causes of infection and to hinder the contamination of the ground. The remarkable work this Commission has accomplished and is in process of accomplishing in the countries chiefly infected is described in the annual reports of the Commission.

Below is the number of persons examined and treated during the period 1910-1923 by the Rockefeller investigators:

<table>
<thead>
<tr>
<th>ALL THE COUNTRIES SUBMITTED TO THE INVESTIGATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of persons examined</td>
</tr>
<tr>
<td>-----------------------------</td>
</tr>
<tr>
<td>4,637,113</td>
</tr>
</tbody>
</table>

As regards geographical distribution, the enquiry has given the following results:

<table>
<thead>
<tr>
<th>Country</th>
<th>Period</th>
<th>Number of persons examined</th>
<th>Number of persons infected (absolute number)</th>
<th>Percentage of infected examined</th>
<th>Persons treated once</th>
<th>Persons treated twice or more (absolute number)</th>
<th>Percentage of infected examined</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southern States</td>
<td>1910-21</td>
<td>1,475,000</td>
<td>518,668</td>
<td>36.7</td>
<td>498,640</td>
<td>239,921</td>
<td>49.0</td>
</tr>
<tr>
<td>East Indies</td>
<td>1915-23</td>
<td>435,999</td>
<td>287,874</td>
<td>66.0</td>
<td>242,916</td>
<td>242,916</td>
<td>91.4</td>
</tr>
<tr>
<td>Central America</td>
<td>1914-23</td>
<td>1,285,573</td>
<td>795,561</td>
<td>62.7</td>
<td>783,460</td>
<td>534,855</td>
<td>70.1</td>
</tr>
<tr>
<td>South America</td>
<td>1918-23</td>
<td>773,879</td>
<td>629,532</td>
<td>81.4</td>
<td>848,206</td>
<td>573,314</td>
<td>67.6</td>
</tr>
<tr>
<td>The East (Australia, China, Egypt, Burma, etc.)</td>
<td>1914-23</td>
<td>495,662</td>
<td>323,930</td>
<td>64.9</td>
<td>1,060,504</td>
<td>457,050</td>
<td>42.9</td>
</tr>
</tbody>
</table>
The proportion of persons infected, therefore, to the total population examined varies from a minimum of 36.7 for the middle States of the United States, to a maximum of 88.2 for the East (of which 75 per cent. relates to China; 93.2 per cent. to Borneo (1921); 97 per cent. to Ceylon from 1916 to 1921). Very high figures have been reported also in Natal (30 per cent. of the coolies on the sugar-cane and tea plantations); in German Guiana (80 per cent. in certain zones), and 90 per cent. of the workpeople in Porto Rico in 1904.

The mortality from anaemia was so remarkable in Porto Rico from 1890-1897 (15 to 15.5 per cent. of all the deaths: 22.13 per cent. in 1898) that the federal authorities were led to take up the matter, believing that poverty and wretchedness could not alone account for it. The committee of investigation reported that ankylostomiasis was the cause, and Dr. Ashford believed the parasite to be Ankylostoma Dubini. Later investigation by Stiles (1902) led to the conclusion that another species was the cause, to which he gave the name Neuctor americanus and which is now known as ankylostoma of Stiles. The propaganda organised among the medical men by the members of the committee — which had now become permanent — led to the creation of dispensaries and sanitary measures which rapidly brought about improvement. At the end of June 1910, 300,000 persons had been treated (a third of the population) and the proportion of the infected, which had been 44.90 per cent. and in certain provinces 50 per cent. fell rapidly.

An enquiry in the Philippines (1922) showed that 85 per cent. of those examined were carriers of intestinal parasites, a half of them being either A. Dubini or Stiles. Most of these carriers, however, were in a good state of health.

In the U.S.A., during the war, examination of 507,000 recruits showed 10 per cent. affected with ankylostomiasis. The Southern States showed the highest figures (Georgia 23 per cent., Florida 32 per cent., Alabama 29 per cent. of the recruits); the Northern States showed the lowest (1 per cent.); the majority of the infected in the North had previously been in the Southern States. In this Argentine Republic infection is rife over a great part of the country, especially among the children. Every day new districts, hitherto free, become infected (T. Tonina, 1923).

The campaign against the infection is of extreme urgency inasmuch as even the minor cases represent an important loss collectively. An American enquiry has reckoned the output of an infected workman as one-half or even one-sixth of that of the normal output, and Dr. Gunn has calculated that the annual loss in output of infected miners in California amounts to 30 per cent.

**Occupations exposed to Infection.**—All occupations affording contact with warm and humid earth are liable to infection from the larvae: agricultural labourers (use of stable and byre manure), planters of coffee, sugar, bananas, cocoa, tobacco, tea, labourers in rice fields, brick-workers (the first case was notified in 1882 in Cologne), pottery workers, tile makers, kitchen gardeners, and peasants.

Tunnelling operations are also a frequent cause of contamination in the absence of necessary precautions. Thus, while the St. Gothard tunnel has gained notoriety for a widespread epidemic affecting thousands of workmen (it has been estimated to have caused 10,000 deaths from anaemia — Perroncito), not a single case occurred among the 25,000 workmen employed in tunnelling the Simplon.

Cases of ankylostomiasis can also occur among excavators, workmen making bridges, canals, etc., but it is of principal interest in coal-mines, where the conditions are most favourable to the life of the parasite. It affects only the deep miners, in whom contamination occurs readily in consequence of the grime on their skin (a mixture of sweat, coal dust and mud).

With regard to dissemination of the disease, the carriers (without any morbid conditions) are the most dangerous. One carrier can contaminate a whole mine. The families of the infected usually remain immune.

The frequency and gravity of the infection vary greatly according to the locality. The number of persons affected also may vary from time to time. When ankylostomiasis attacks a mining area for the first time the symptoms are usually severe, but as time elapses the miners seem to suffer less (diminution of the virulence of the parasite and increase in the resistance of the miner). Infected shafts have been observed close to others unininfected in the same mine, especially where men work in a sitting posture (St. Etienne, France).
Infected Coal Mines. — Australia: In the campaign against this infection, out of 5,063 coal-miners in Queensland and New South Wales, 644 were found to be infected with ankylostomiasis by the special commission appointed. Contagion was due to defective installation of pits and consequent contamination of the water and the faeces. The measures taken, combined with education of the miners, reduced the number of infected persons from 31.5 to 6.1 per cent. (W. C. Sweet, Congress of the British Medical Association, Australian Section, 1923). The metalliferous mines are practically free from it. In fact, amongst 10,228 workers occupied in 156 mines in six States, only 644 contaminated persons were found (6.3 per cent.).

Austria: Generally speaking, the mines do not present the local conditions favourable to the development of infection. Cases usually come from abroad. Ankylostomiasis has been rapidly eliminated by strict observance of the measures laid down in the Ministerial Decree of 4 September 1904 (see under Legislation, p. 142).

Belgium: The mining basin of Liège was, thirty years ago, the most infected in Belgium; successive commissions of enquiry revealed upwards of 50 per cent. of carriers of ankylostoma in certain mines. The general average of carriers for this area in 1900 was 26 per cent. among about 30,000 miners.

The basin of Charleroi was much less affected. In that of Mons, ankylostomiasis rages intensely in certain mines, there being as many as 70 per cent. carriers, but, on the whole, there were fewer affected than in the district of Liège.

The campaign was concentrated principally in two organisations at Liège and Mons — the "Miners' Dispensaries to Combat Ankylostomiasis". Here microscopical examination of the dejecta of the workers engaged was made, and anti-parasitic treatment applied. Further, several firms organised a service of their own, comprising examination and treatment provided to medical men attached to their mine. The activity of these organisations has reduced, year by year, the percentage of carriers to such a point that, in the Liège basin, where the results are the most striking, in 1923 only one carrier was found among 26,000 examinations of dejecta of workmen in different coal-mines. The actual danger lies in the engagement of numerous foreign workmen, among whom carriers of ankylostoma (workers from North Africa) and of other intestinal parasites are found.

Bulgaria: Bulgarian miners were immune up to 1910.

Chile: In 1910 Fernandez, after examination of 950 miners, found that the percentage of workers affected varied from district to district. He found, in fact, percentage varying from 6 per cent. to 72.5 per cent. of those examined.

France: At the moment there is no ankylostomiasis in French coal-mines. An enquiry made in 1905 by Dr. Potelet, at the instigation of Dr. Calmette, on 17,153 of the 77,396 men employed in the mines of the Nord (nearly 23 per cent.) showed that 527 (3.07 per cent.) were found to be carriers. The men drawn from 23 coal companies were also found to be immune. In other firms the percentage infected varied from 0.11 per cent. to 60 per cent. Among these 23 firms thirteen cases, that is, 32 per cent. were infected, the infection having been imported. In other firms the number of mines is considered.

Morbidity is practically absent from mines of the North of France because of their dryness. The carriers did not become infected at the cutting face, but, even if this had been the case, it would have been impossible to take any of the ordinary precautionary measures because of the arrangement of the approaches as soon as the seams are reached. In the passage-ways used by the miners in reaching the coal-face, however, there is nearly always some water trickling down the walls. The gutters for carrying this water ought to be replaced by covered drains. In the St. Etienne region the enquiry of Briacon (1904), relating to 1,200 miners, showed the fact that though the workers in certain shafts were contaminated up to a proportion of 92 per cent., other shafts were immune. Altogether, he found that about 5 per cent. of the miners were carriers and that there had never been a real epidemic, although infection was permanent among them.

Germany (Rhenish area): In 1902 the average number infected did not exceed 9 per cent. In two years the numbers of parasites had fallen by 85 per cent.; this success was due to prophylactic measures applied with requisite energy and discipline and the disposal of adequate financial means to impede microscopical examination of dejecta on engagement, compulsory treatment, etc.).

Hungary: The mines of Selmezchanya and Kormabanya were infected (1882-1892), but ankylostomiasis has completely disappeared thanks to the installation of
pails in the mines and prohibition of defaecating elsewhere than in them.

India: In the coal-mines of Bengal 70 per cent. of the miners are carriers without apparent sequelae (Tomb, Indian Medical Gazette, October 1923).

Italy is affected as regards its sulphur mines (Romagna and especially Sicily), where at the time of the health enquiry (1899) 80-90 per cent. of the miners were infected. (See article "Sulphur").

Netherlands: The first general enquiry took place in 1904 in the mines of South Limburg, carried out by Drs. Girms and Backer, the second in 1907 by Drs. Kranenburg and Kuijjer. The enquiry yielded the following results:

<table>
<thead>
<tr>
<th>Number of miners</th>
<th>Infected</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,389</td>
<td>300</td>
<td>21.740</td>
</tr>
<tr>
<td>2,653</td>
<td>54</td>
<td>2.068</td>
</tr>
</tbody>
</table>

In 1907-1908 Dr. V. Putten examined the brickmakers in South Limburg. The carriers here were ascertained to have worked in Belgium and Germany; 14.5 per cent. were found to be infected.

The sulphur mines of Central Russia and of the Balkan States are also infected (no recent data).

In general, mines in which the infiltrating water contains salt, even merely the small percentage of 1 grm., are immune (e.g. St. Just, in Cornwall).

In the tin-mines of Cornwall and Devon (in 1894 and 1902) 38 per cent. of the workers were affected. Here also portable pails and compulsory treatment (from 1905) have proved very successful. In 1908 not a single case of sickness was reported although 80 per cent. of the workers were still carriers. In other mines infection was less serious without cases of sickness.

Other infected mines are gold and silver mines in Hungary, and lead mines in Spain (reported as the most infected mining centre — 80-90 per cent. of the workers). (For metalliferous mines, see Australia.) No case has been reported from any quicksilver mine.

Only one detailed study of the geographical distribution according to country exists — that of Siccardi in 1909. In this an analysis of 571 Italian papers is given showing that 45 out of 69 Italian provinces were infected.

**PATHOLOGY**

The disease is extremely protean, varying according to the predominance of one or another symptom. Carriers showing no effects must be distinguished from the really sick, suffering from anaemia. This is of prime importance in regard to prophylaxis.

From the clinical point of view the infection can be slight, moderate, or severe. After an incubation period varying from three weeks to one or two months, there follows the period in which severe anaemia is the most marked symptom, due, it would appear, rather to the secretion by the salivary glands of the worm of a haemolytic toxin, than to mechanical factors.
action following on the mucous haemorrhages provoked. Though abdominal pains, nausea and vomiting are rare, the following general symptoms are common: feeling of fatigue, malaise, lassitude, dyspepsia, sometimes diarrhoea.

The skin is hard, dry, rough, sometimes atrophied. A trained medical man can at this stage recognise the existence of cutaneous lesions situated generally on the feet and legs and on such parts as come into contact with infected matter (e.g. the forearms).

At the period of onset there is frequent vertigo, dyspnoea, precordial oppression, in most cases slight fever (38°-38.5°), continuous or intermittent

**Digestive Tract:** The appetite is increased (in serious cases hyperoreia), perverted taste (ingestion of earth: Indian and negro earth eaters); epigastric pains with nausea and vomiting, increasing salivation; obstinate constipation alternating with diarrhoea; foetid stools, distension of the abdomen (dilatation of the stomach), slight ascites, rarely jaundice.

**Circulatory System:** No cyanosis (except in cases of cardiac insufficiency); signs of overwork of the heart. In severe cases slight hypertrophy. Dyspnoea and palpitation, either spontaneous or as the result of slight effort, vertigo, buzzing in the ears, headache, tendency to syncope,

![Fig. 15. — Larva of ankylostoma during passage into the lung. (Prepared by Dr. Lambinet, Liége.)](image)

(not returning to normal between the attacks) and not related to the number of parasites but rather to the severity of the anaemia; ceasing often after expulsion of the worms.

The tint of the skin is typically yellowish green (dirty especially among the mulattoes). Sweating is diminished and in serious cases even suppressed.

The face shows definite puffiness especially marked on the eyebrows and cheeks.

**Respiratory Tract:** Sometimes there is bronchitis with frothy mucous expectoration, in which the larvae can be found. Sometimes epistaxis. In severe cases the cardio-vascular symptoms seem to dominate the gastric. Oedema of the legs and feet is generally late in appearing (although it may be early).

No marked emaciation occurs; the muscles are flaccid, weak, simulating paralysis, and there is profound asthenia.

**Nervous System:** Mental activity is reduced; there is an expression of melancholy. The patient loathes his work, is indifferent, idle, prone to fall asleep. In the worst cases there is depression, mental confusion, knee jerks, exaggerated or diminished,
sensitiveness to cold, tickling sensation or sensation of deadness in the feet. Sometimes there is pseudo-maniacal or pseudo-melancholic psychical state, hystero-epilepsy, etc.: nevertheless, the state of nutrition generally remains good.

Special Senses: Visual acuity is diminished and pupils dilated; cataract is rare. Diplopia, optic neuritis, retinal haemorrhages. In miners the anaemia predisposes to nystagmus.

Blood: Examination shows a diminution in the haemoglobin and in the number of red cells (2,500,000 to 2,000,000 or less), morphological changes in the red cells (microcytosis especially), macrocytosis, myelocytosis and numerous megaloblasts.

After a varying period all the signs of pernicious anaemia appear. The blood loses its colour and consistency in proportion as the anaemia progresses. In very severe cases it is pale, thin, and has the appearance of being washed. The leucocytic count is very variable and without characteristic value. There is no marked leucocytosis, and sometimes even leucopenia. On the contrary, marked eosinophilia (10-17 per cent. or more instead of 1 to 2 per cent.). The eosinophils are larger than normal, and fragile with tendency to degeneration; they persist after the expulsion of the worm and have no relation to the number of these; they can exist even with other worms. In several cases eosinophilia is not present and the small number of eosinophils may not indicate increased severity of infection.

Efforts to find a specific precipitin in the serum of persons suffering from anaemia due to ankylostomiasis have been fruitless.

Urine: A trace of albumen may be present, also cylinders, urobolin, peptone and indican according to the degree of infection. The amount of urea is often less than normal (severe cases with malnutrition).

Faeces (see under Diagnosis, p. 140): The presence of the intestinal anguillula at the same time as ankylostomiasis is exceptional; that of the ova of ascaris is more frequent, also that of the ova of trycocephalus.

Skin lesions: Infected persons always say they have sensations of itching or burning on some part of the skin. The skin shows at an early stage an erythema which becomes papular, then vesicular, most frequently papulovesicular, and terminates in a form of eczema, tuberculous urticaria. These lesions carry names varying according to locality: "bunches" in Cornwall, "mazzamora" at Porto Rico, "pitirru" in Sicily, "gourme des mineurs" in France, "panighao" in the tea plantations of Assam, and still other names in America such as "toe itch", "ground itch", "water itch", "water pox", etc.

Spontaneous cure results at the end of a period more or less long, but rapidly under suitable treatment. Certain localised ulcerations above the ankle are resistant to all symptomatic treatment, yet always heal after antihelminthic treatment.
From the social point of view, ankylostomiasis should command attention by its pernicious influence on the physical and mental development of children affected and even on the progeny of infected persons: late appearance of puberty, of the menses, impotence in men, amenorrhoea, sterility, and miscarriage in women. Young persons infected for years show the typical appearance of infantilism or dwarfishness; feminine look, arrested development of the sexual organs, evidence of disthyroidism, with hypertrophied thyroid more or less degenerate or sclerosed.

Course: Left to itself ankylostomiasis goes on for years. It can last for 4, 5, 8, and even 15 years without complications. Rapid cure results after suitable treatment. Sometimes the anaemia persists even after recovery. Relapses are frequent. Though a fatal termination is rare in Europe, it is less so in tropical countries where ankylostomiasis complicates other diseases peculiar to these countries. It is a debilitating malady which diminishes resistance to other morbid influences (especially tuberculosis). The *Necator* or *Ankyl.* of *Stiles* has obviously a worse influence on the development of infection than the *Ankyl.* *Dubini.*

Immunity: Apart from an immunity in certain persons with long-standing infection, there is relative immunity in the black races. Very important is the relative immunity of certain carriers who show but the slightest trace of infection or even none at all.

**Diagnosis**

Examination of the faeces is indispensable because the symptoms in many of the cases may lead the untrained physician to form a wrong diagnosis. The existence of a progressive grave anaemia, the special pallor in persons exposed to infection, ought to direct the attention of the doctor to the necessity of looking for the ova of ankylostomiasis in the faeces as the only positive evidence. The faeces should be examined within 24 hours of evacuation because microbial fermentation alters the ova (a saturated solution of sodium chloride preserves them). By direct examination the ova only show if they are very numerous. Although the method of examination gives an immediate result, it does not suffice for discovering all the carriers. It is necessary to have recourse to processes of enrichment. Teleman's method (to treat the stools with ether and hydrochloric acid and centrifuging) allows of accurate diagnosis in the case of 55 per cent. of the carriers and gives an immediate and satisfactory result. By the method of bringing to the surface (diluting the faeces with sodium chloride, agitating and then allowing them to stand), the ova float on the top and attach themselves to a coverslip placed in contact with the surface of the liquid, etc. The sedimentation method or the method of culture (proposed by A. Looss) reveals 99 per cent. of the carriers, but is not practical for all medical men as it requires at least five to six days.

A gramme of faeces can contain 15,000 to 20,000 ova, which represents one thousand parasites. It has been shown, however, that the number of worms in the intestine is not always so high (see above). Recently, Stoll (1923) calculated that a female parasite produced approximately 9,000 ova per day, so that in certain cases the number of ova might reach several millions. But it should be added that only about a quarter of the ova produced are viable.

The characteristic appearance of the ova prevents likelihood of confusion with those of other parasites.

The following data will serve for differentiation of the two types of ova:

*Ankylostoma Dubini.*

- **Length:** min. 44 microns.  
  max. 67 
  **Average:** 52-64
- **Breadth:** min. 22 
  max. 42 
  **Average:** 40
- Double outline apparent.
- Shell thicker.
- Generally at the commencement of segmentation 12 to max. of 4 blastomeres.

*Necator Americanus.*

- **Length:** min. 62 microns.  
  max. 82 
  **Average:** 72
- **Breadth:** min. 38 
  max. 56 
  **Average:** 55-56
- Double outline very close and very difficult to bring out.
- Shell thinner — more easily broken under the coverslip.
- More frequently in an advanced stage of segmentation (8-16 blastomeres).

**Direct examination for the parasite** should be made after administration of a vermifuge; examine three differ-
ent stools; dilute the faeces with water, sift carefully.

In 1916 White proposed to examine for traces of blood in the faeces. This indirect method takes as long as examination for the ova, and naturally has only a very relative value. Examination for the crystals of Charcot-Leyden and cholesterine has only a complementary value.

Examination of the Blood: A leucocytes count has no positive value. Eosinophilia at the same time has been the only guide for diagnosing exactly the anaemia of Porto Rico (Dr. Ashford), but exaggerated importance ought not to be attached to it; it is only a complementary element in diagnosis.

Deviations of the complement, the monistagminique reaction, etc., are not necessary if so simple and neat a method as that of examination for the ova is employed.

Examine for larvae in specimens of earth (method devised by Nocht (Java) in 1917).

Prophylaxis

Prophylaxis has several aims: (1) to prevent dissemination of the ova of the parasite (most important, especially for mine and tunnel work); (2) to prevent the development of the larvae and destroy those that are already adult; (3) to prevent all transmission of infection by water, earth, mud, etc.

The necessary measures should never be employed separately or the campaign will be long, difficult, and perhaps unsuccessful.

The Rockefeller Foundation has inaugurated since 1915-17 a campaign against ankylostomiasis in the island of Antigua with 7,200 inhabitants. Infected persons numbered 29.8 per cent. of the population; 1,972 persons have been declared cured. A portion of these, examined in 1925, showed 21.2 infected. The improvements made had declined. Treatment alone, therefore, is not enough; it requires to be completed by a whole series of sanitary measures, by education, etc., effectively organised.

1. Commence with two kinds of measures.

(a) Note the sick and treat them.

(b) Prohibit defaecation on the ground.

All measures taken are dependent on the co-operation of the population, and unless the workpeople recognise the danger and have been educated in the steps which it is necessary to take, these are unfortunately likely to be of very little practical use.

If the industrial situation permits it, and if financial means are available, it would naturally be advantageous on the practical side to stop work for some weeks and undertake sanitary measures both in relation to the workers and their surroundings.

(i) Examination of the workers: no workman should be engaged for mine work unless he is immune (Germany, England, Austria, Belgium, etc.). Further, provision should be made for unexpected developments by periodic examination of the personnel of the undertaking; the examination should extend to every well in the mine shaft and to the defecation of 20 per cent. at least of the personnel. If a single carrier is found, the examination should be extended to all the miners. Prohibit the infected from mine work until they are completely cured.

Treat the sick and carriers by the methods now recognised as the most effective. They should be treated in dispensaries or hospitals, as domiciliary treatment is not to be recommended, supervision being impossible.

The most efficacious method to combat the infection is undoubtedly to treat all the infected subjects, because in this way the source of infection can really be attacked, even in circumstances where it is difficult to limit infection of the soil. The efficacy of this method is greatly heightened if the treatment is repeated with a view to the reduction of re-infections and be putting it into operation whenever practical during the cold or dry season, that is, when the infection of the soil is at its minimum. The application of this method minimises in a few days' time the number of embryos reaching the ground.

(ii) Place in the galleries numerous serviceable metal pails at the most likely points. Special attention should be paid to types which are in keeping with the workmen's habits. Water-tight pails must be carefully and regularly removed and disinfected by a personnel specially charged with the task. One pail for four workers was the rule in the campaign organised in Westphalia. See that penalties are exacted in the case of persons who fail to use them. They are compulsory in Germany (in the Dortmund district since 12 March 1900), in Austria (since 1900), Belgium (in Liège since 4 November 1904), etc.

In mines where the galleries are numerous, narrow, and low, or where
the roads are confined (e.g. in the coal-mines of the North of France) they may be difficult to employ, but in such cases a truckle system is possible.

Commendious latrines also, sufficient in number, may be placed near the approach to the mine or tunnel, and efforts made to habituate the workmen to use them before descending the shafts or entering the tunnel.

2. The contamination of the ground can cease in two or three days as a result of the action of rain and insects (especially the larvae of Drosophila and other flies). But under favourable conditions the larvae develop in five to fifteen days.

Covering the faces with clay, cinders or coke and burying them at a depth to about 30 cm. is not sufficient to prevent the development of the larvae, which can rise to the surface of the soil. They develop in a sandy soil at a depth of 90 cm. and work their way up from there, but the number of larvae which rise is proportional to the depth. On the other hand, pure clay does not allow the larvae to rise even from a depth of only 18 cm. below the surface.

Numerous measures are applicable in special cases according to circumstances. Thus the problem of dealing with the subsoil water arises; in mines active ventilation of the galleries is necessary; drying of the galleries and passage ways (arrange for the water to get away, prevent stagnation, remove mud, etc.), good maintenance of the ways, suppression of dripping of the water by drainage, etc. Diminution of the temperature with less humidity would mean the creation of conditions unfavourable to the development of the ova and larvae.

Disinfection of the galleries of the mine or of pathways is also useful. Carboic acid 5 per cent., milk of lime 10-20 per cent., caustic potash or soda 5-10 per cent., ferrous sulphate and cooking salt 10 or 20 per cent. have been suggested, but the results are not very satisfactory; the substance used, even if very concentrated, is rapidly diluted by the water in the galleries or subsoil or undergoes chemical change resulting in less efficacious products. The duration of the disinfecting action is, therefore, limited. Lime was recommended in 1900 by Van Ermengen and Thenolt (Belgium), and studied by Lambinet, of Liège, and by Previtera in Italy. Milk of lime (5-10 per cent.) has some action on very young larvae; for ova and adult larvae a 20 per cent. solution acting for three hours at least is required.

Cooking salt was suggested as a disinfectant for the first time by Perroncito, and first practically applied in a 2 per cent. solution by Manouvrier in 1905. Previtera lays stress on the fact that a 3 per cent. solution is necessary to kill young larvae rapidly. Use of salt, however, makes the galleries slippery, and this greatly interferes with the work of the miners who push the trolleys; the undissolved crystals, moreover, injure the feet and cause a burning sensation, especially if the skin is abraded. Crushed salt or saltina 20 per cent. solution is thrown on the ground: it is very useful against young larvae and ova but without effect on encysted larvae.

3. Prevention of the transmission of the parasite is effected by good drainage of waste water, especially provision of good drinking water (so that there is no chance of contamination). Installation at the surface of douche baths, cloakroom and washing accommodation, etc., in order to facilitate as much as possible cleanliness of the workmen on their arrival at the surface or on leaving the tunnel (Germany since 1900, Belgium, etc.).

At the place of work basins should be provided with salt water (5 per cent.) for washing the hands and the tools and articles which have been in contact with the ground. Similarly, provision of foot-baths on leaving the lifts are useful (this is difficult of application).

Avoid, as far as possible, contact of uncovered parts of the body with earth (especially the hands and face): this is a pious expression of opinion, as in hot climates and in mines the workers are often naked (e.g. sulphur mines of Sicily).

Compel the workmen to wash their hands before meals: part of a general hygienic health propaganda.

Emigrants. — Compulsory examination of emigrants from infected countries should be considered as indispensable as also treatment of carriers. The length of the transatlantic voyage allows of the application of these measures being more easily effected than at the port of disembarkation.

Treatment belongs to the medical man.

Legislation

Compulsory notification: Germany, Bavaria, etc. Belgium, Brazil (agricultural labourers). Great Britain (since 1900), Hungary, Illinois, Netherlands (since 1911), New Zealand.
Compensation on the same lines as accidents, but only for cases of ankylostomiasis among miners: Alberta, Argentina, West and South Australia, Germany, Illinois, New York, New Brunswick, Nova Scotia, Ontario, Great Britain, Russia.

Compensation also for carriers: Great Britain, Queensland, Western Australia (mines, quarries, stone breaking and dressing).

Compensation is provided without specifying the occupation in Argentina, Bolivia, and New York.

Special Legislation.

**Austria:** Circular of 4 July 1904 of the Minister of Agriculture to the Inspectors of Mines at Vienna, Klagenfurt and Gracow prescribing the prophylactic measures: examination on commencement of employment, pails, prohibition of depositing stools on the floor of the galleries, etc.

**Belgium:** Numerous Royal Decrees as regards preventive measures in the coal-mines. A Decree of 24 October 1904 requires the provision of pails; another of 4 November deals with infected mines in the neighbourhood of Liège (douche baths, etc.). In 1906 a Decree affecting Hainault groups the mines, following on the result of an enquiry made. If they are free, notification of any case that may occur in the future is required; water closets at the surface (1 to every 25 persons) as near the shafts as possible; movable pails below ground, capable of being closed, provided with deodorants, and to be steam-disinfected once every 24 hours. If the mines are infected, the Decree requires medical examination of all the workmen.

It was, however, only after 1919 that the Minister of Labour organised by a series of Royal Decrees (30 June 1919, 31 December 1920, 7 March 1921, 17 October 1921), measures applicable to limited localities, but to all the five coal mine areas of the country. The principal measure is microscopical examination of the stools of every workman on commencement of employment and six weeks later. The Ministry of Mines can require examination of every underground workman if there is danger to fear from contamination of the waxes; the coal-mines have to undertake at their own cost the anti-parasitic treatment proposed for carriers. All these measures are applied at the prescribed time whether, as in the Liège district, the microscopical work necessary (about 30,000 examinations a year) is centralised in the central dispensary for examination and treatment of the carriers, or, as in the other districts, the microscopical work is carried out by medical men attached to the coal-mines, provided that the latter, after attendance at the special course in parasitology, have received the approval of the Minister of Labour as to their competence.

**Brazil:** Decree of 18 June 1919, No. 5010.

**France:** The Decree of 17 June 1913 prescribed the compulsory treatment of infected mines.

**Germany:** Act of 12 March 1900 requiring provision of movable pails in galleries, douche baths, cloakroom and washing accommodation, etc. Penalties for not applying to mines in the district of Dortmund requires a medical certificate on commencement of employment stating that the workman is free from ankylostomiasis, with examination within six weeks following and compulsory treatment of carriers.

**Great Britain:** The measures were already provided for in section 27 of the Metalliferous Mines Regulations for Devon and Cornwall.

In the Dominions: Ceylon Acts of 8 June 1917, No. 6879, and 2 September 1917, No. 6897.

**Italy:** Circular of 30 March 1901, No. 20300, of the Minister of the Interior and the Act of 14 July 1907, No. 357, on the subject of the compensation to workmen suffering from ankylostomiasis employed in the sulphur mines.

**Netherlands:** The preventive measures against the spread of infection among the miners date from 1906 (Ztrbl. No. 248, Art. 207, e.v.), but modifications of the regulations are at the moment in preparation. They relate to medical examination, washing and bath accommodation, sanitary conveniences, drinking water and overalls.

**Spain:** Measures decreed in 1912.

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Prof. Malvoz (Liège).

**Anthracene**

**French:** Anthracène. — **German:** Anthracen. — **Italian:** Antraceno. — **Spanish:** Antracena.

**CHEMICAL PROPERTIES**

Anthracene is a hydrocarbon found in small quantities (0.25-0.45 per cent.) in coal tar and derived from the less volatile part by fractional tar distillation above 270° C. i.e. from anthracene oil (also called green oil). Anthracene oils contain about 2.5-3.5 per cent. of anthracene in conjunction with naphthalene, diphenyl, pyrene, etc. If the

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**CHEMICAL PROPERTIES**

Anthracene is a hydrocarbon found in small quantities (0.25-0.45 per cent.) in coal tar and derived from the less volatile part by fractional tar distillation above 270° C. i.e. from anthracene oil (also called green oil). Anthracene oils contain about 2.5-3.5 per cent. of anthracene in conjunction with naphthalene, diphenyl, pyrene, etc. If the
fractional distillation be carried further, purified anthracene or anthracene at 50 per cent. is obtained.

Raw commercial anthracene, known as technical anthracene, is in the form of a crystalline mass — yellow to brown in colour, with an odour similar to that of naphthalene — and contains 30-90 per cent. (mostly 60-50 per cent.) of pure anthracene. Pure commercial anthracene C14 H10 is in the form of brilliant white crystalline flakes with violet fluorescence. It boils at about 360° C., melts at about 213° C., and sublimates easily, giving forth an irritating odour; it is insoluble in water, slightly soluble in alcohol, ether, and benzene, and easily soluble in boiling benzol.

**INDUSTRIAL USES**

Purified anthracene is mixed with potassium and distilled in iron retorts. Impurities (chiefly carbazole) are thus eliminated and a non-volatile compound of potassium is obtained. The distillate consists essentially of anthracene and phenanthrene which are separated by means of toluene. By repeated crystallisation, using benzene, pure anthracene is obtained.

Anthracene is used in the preparation of anthraquinone, which again is used in the production of alizarin and other dyes (aniline colours). Crude anthracene oil is sometimes employed for giving a preserving coat to wood and it is also used as an agglomerating agent for briquettes. Anthracene oil is often added to sulphonated machine oils because of its lubricating properties and cheapness, forming an ingredient of the so-called "soluble oil" or "screwing mixture".

**SOURCES OF POISONING**

The following categories of workers are exposed to the effects of anthracene: workers engaged in the production of anthracene and of anthraquinone, workers handling certain artificial organic dyestuffs — alizarin dyes, vat dyes, mordant colours, so-called tar colours — workers using an anthracene preparation for coating wood, makers of briquettes, makers of lubricating compounds containing anthracene, and workers in engineering shops using such compounds.

**TOXIC ACTION — SYMPTOMS**

Anthracene acts as a strong irritant of the skin and the mucous membrane, and the injury to the skin caused during the production and use of anthracene often results in serious skin diseases with eruptions usually on workers' hands, forearms and feet, which may later develop into cancer.

This action may be produced even on contact with products containing minimal percentages of anthracene. Doubt exists as to whether injury is the result of the anthracene itself or of impurities contained in it. Grandhomme denies that it exerts an injurious influence. Other authorities pronounce it harmless when free from phenol, cresol or carbazole, while certain authorities are of the opinion that the irritation produced by briquette making is due to a mixture of anthracene and not in the anthracene oil itself.

Cases of dermatitis and of cancer caused by anthracene have been noted particularly amongst workers tending machines lubricated with this product. In certain factories where more expensive mineral oil was replaced by anthracene oil numerous cases of skin eruption occurred. Oliver cites cases of dermatitis on the hands and arms of workers employed in making "coal grease", a mixture of heavy crude oil and anthracene oil, with the same quantity of resin and lime. Amongst those workers who had received hot splashing on the hands, forearms and face, two cases of epithelioma of the forearm were reported. Amongst 25 workers handling anthracene, cases of epithelioma were also recorded (3 cases affecting face, hands and wrists). An overgrowth of epithelial tissue has been produced experimentally in rabbits by injecting an anthracene dye.

Data relating to the frequency of cutaneous lesions due to anthracene are not of recent date. In 1904 the management of a large factory of chemical products in Germany conducted an inquiry into the health of workers engaged on the manufacture of anthracene. During ten years 22 out of 30 workers employed presented an erythematous dermatitis localised on the hands and arms, and neck; 3 had to be operated upon for cancerous ulceration of the scrotum. They had worked in the anthracene department from six to eight years.

A German inspector in the Arnsberg district in a survey (1906) of 9 establishments for the production of anthracene found very few cases of eczematous affections.

According to O'Donovan, workers handling the "crude cake" are most affected, those dealing with the purified product being but slightly involved.

Besides dermatitis (eczema) and epithelioma, lesions such as acne, kera-
tosis, telangectasis and pigmentation are common. Growth are unlike those of tar cancer, being solitary with no metastases.

According to numerous observations made, anthracene fumes are capable of causing a lesion of the delicate and sensitive skin of the eyelids rather than of the conjunctival mucous membrane. Certain experts consider, however, that this action is due to acridine rather than anthracene.

**Hygiene**

The use of anthracene oil in cutting compounds should be discontinued unless in such reduced proportions as to be harmless. In all other industrial operations where the product is handled, workers should have their hands and faces protected from contact with it.

**Legislation**

Cancerous dermatitis due to anthracene is included in the German list of diseases assimilated to accidents for the purpose of compensation. (See also articles "Tar", "Paraffin", "Tumours").

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**Anthraquinone**


Anthraquinone [formula, \((C_4H_2O_3)\)] is obtained by oxidising pure anthracene by means of sodium bichromate and sulphuric acid. One hundred parts of anthracene (95 per cent. strength) yield 110 parts of crude anthraquinone, which is purified by sublimation by steam or by dissolving it in hot concentrated sulphuric acid and precipitating again with water. In this way 80 to 85 per cent. of pure anthraquinone is obtained.

The substance can be obtained also by electrolysis of anthracene in the presence of sulphuric acid and salts of cerium or manganese, or by oxidising anthracene by nitrous fumes, or iron salts, in acid solution.

Anthraquinone occurs in the form of clear yellow crystals or as a white powder (if finely ground). They melt, when the product is very pure, at 284° C., while commercial anthraquinone melts at 273–277° C. It also sublimes readily. Insoluble in water, and very slightly soluble in alcohol, ether and benzene, it dissolves readily in boiling benzene, glacial acetic acid and strong sulphuric acid.

By sulphonation, nitration and chlorination, etc., anthraquinone yields several useful derivatives for the preparation of synthetic organic colours.

It is *used* in the preparation of artificial alizarine, which is a dioxyanthraquinone, and other anthraquinonic colours (quinizarine, purpurine, anthraquinone red, etc.), as a catalytic agent, etc.

Some of the ill-effects recognised from use of ursol (" paraphenylene-diamine", see that article) are attributed to the action of anthraquinone. Other ill-effects occurring in the course of the manufacture of the substance have been attributed to pyridine (see that article).

Similarly, in the case of the group of substances of the fluorescent azines, having the property of damaging the cells of the higher organisms where exposed to light, while remaining inactive in the dark, e.g. the series of acridine, anthracene, xanthone, anthraquinone show the same effects.

Lewin has described how workmen in a cardboard-box factory, using a cement made from pitch, suffered from an itching or burning sensation of the skin and face, neck, arms, etc., and showed diffuse redness of all these areas.

Of 103 men affected, 85.4 per cent. only suffered discomfort when they exposed the parts to the action of the sun or light; 25 showed lesions both in light and shade. Blond persons were most affected (86.4 per cent.). According to Lewin, acridine was the cause of this dermatitis, but neither anthraquinone nor certain products of the series could be excluded as playing a rôle.

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**Anthrax**

(French: Charbon. — German: Milzbrand. — Italian: Pustola maligna. — Spanish: Carbunclo.)

An infectious disease common to animals and man, due to a specific microbe, the anthrax bacillus, anthrax affects certain kinds of animals particularly: sheep, goats, oxen, horses, and, less frequently, swine.
The anthrax bacterium is an immobile rod, cylindrical, homogeneous, and transparent, from 3 to 8 microns long, and 1 to 1.17 micron broad. The ends are a little swollen and slightly concave, so that, when two bacilli are joined, a space between them is left.

The bacilli are sometimes united to one another in chains of two or three. In culture it assumes a filamentous wavy appearance such as it never has in the living animal.

Elimination is by way of the urine, the faeces, and the nasal secretions. It spreads on the soil and in manure, where conditions favourable to sporulation are present. The offal of anthrax-infected animals and the skin, hair, horns, etc., infected with spores can keep their power of growth for a very long time.

The bacilli can be found in abundance (especially some hours before death) in the blood and tissues of infected persons.

The bacillus multiplies by fission, but when the conditions of the medium are unfavourable it changes, generally in a few hours, into the resistant form of the spore. Sporulation, however, never occurs in the living animal nor in the body of animals that have died of the disease. Under such conditions the death of the infected animal prevents access of oxygen to the bacillus, with which it cannot dispense. But if the body is opened or — as frequently happens — if death is accompanied by spontaneous haemorrhages, sporulation formation is rapid. Outside the body the bacillus can exist in a state of suspended animation for a very long time even in media entirely deprived of nutritive elements (earth, water, surface of the body, etc.) and preserve their virulence up to the time when conditions become favourable for their development and the spread of infection.

Kuylenstierna has shown that the bacilli begin to produce spores at an atmospheric pressure of 150 mm. of mercury; at 600 mm. mercury the quantity of spores produced is nearly the same as at 760 mm.

It is noteworthy that agricultural work, running streams, worms, insects, and especially snails, favour conveyance to the surface of the ground of spores which have escaped from the body. Flies, insects, etc., are also means by which infection is spread to a distance. Recently (1924) Tabusso has proved that birds of prey, and particularly the Cathartesex atratus, play in Peru an active roll in spreading the disease, through their faeces, which contain the pathogenic germs in high virulence.

As regards susceptibility to infection, the human subject holds a position between very refractory species (dogs, birds, carnivorous animals) and those very susceptible (sheep, oxen). This susceptibility also varies much in different subjects.

Natural immunity does not exist in man, but a first attack does confer it in considerable measure. Generally anthrax does not recur. Artificial immunity can be conferred by treatment with serum (see below).

The virulence of the bacilli increases by successive passage through animals more and more resistant, and diminishes, with preservation of its power of growth, by exposure to different physical and chemical agents (unfavourable temperatures — too high or too low — sunlight, antiseptics, compressed oxygen, etc.). The bacillus is not more resistant than any other microbe to the action of physical or chemical agents. It requires three conditions for its growth and development: (1) suitable nutrient media either neutral or slightly alkaline; (2) presence of oxygen (the bacilli multiply the more rapidly the greater the proportion); (3) a temperature varying between 18° and 45° C. with an optimum (especially for sporulation) of 35° C.

**DANGER OF INFECTION**

In the majority of cases the malady is occupational in origin, either from contact with infected animals and their products, or by handling the products derived from them.

(a) Agricultural anthrax is by far the commonest form. Generally it is due to direct infection from the bacillus, rarely the spore, and attacks persons engaged in looking after diseased animals and manipulating the products of animals that have succumbed to the disease: shepherds, cultivators of the soil, veterinary surgeons, knackers, butchers, gutscrapers, meat carriers, workers in slaughterhouses, etc.

(b) Industrial anthrax is an infection, indirectly caused by the spore—rarely by the bacillus. This kind of infection is less frequent than the former, but is nevertheless sufficiently widespread. According to some estimates, danger is greater than is admitted to-day because, as a consequence of the difficulties of diagnosis, the number of notified cases is less than those which actually occur.

Among the industries liable to infection are:

1. The hide and skin industry. Especially affected are the workers employed in warehouses and tanneries (contamination through abrasions). The other operations involve less risk. Even after finishing, hides and skins can still be dangerous (cases among bootmakers, saddlers, and furriers).

The effluent from tanneries is a very important means of spreading anthrax spores in fields near the factory (infection of cattle at pasture, and even indirectly infection of cattle from hay). Hides and skins from China, Russia, etc., are notoriously dangerous.
2. Wool industry. Among workers engaged in sorting, carding, combing, and spinning wool coming from Turkey, Asia Minor, Persia (Alpaca, etc.), contamination takes place especially from infected dust (occurrence of the clinical form of internal anthrax was frequent in the past). (See below: Pulmonary Anthrax, p. 149.)

3. Hair industry. Very dangerous in so far as hair of horses and cows is concerned. Risk of infection is by way of the respiratory and digestive tracts (pulmonary and intestinal anthrax), to persons employed in sorting, heckling, carding and carding in factories for the manufacture of brushes and brooms. Even manufactured hair as delivered to the public (shaving brushes and ordinary brushes) can cause infection.

4. Industry for the working up of horns, hoofs, bones, blood, etc. Horns come mostly from India and China. Of the three operations they undergo — blunting, splitting, and planing — the last, consisting in scraping and smoothing the horn previously sawn in two is the most dangerous owing to the dust produced. Dry horns are said not to be dangerous but become so after undergoing a maceration of three weeks to remove the crust.

5. Transport industry. Risk is run by those charged with the transport of the bales of skins at the ports (dock labourers, wharfingers), warehousemen, on the railway and on arrival at the factories, and those engaged by sailors doing similar work on board ship. Contagion from man to man is very rare. In 1922, however, a case was described in Germany affecting the mother of two young boys who had contracted external anthrax from slaughtering an animal. The mother contracted the disease from infecting her sons. She fell ill seven days after them and died of pulmonary anthrax on the fifth day of the disease.

Statistics

Statistics collected in relation to animal anthrax are as follows:

<table>
<thead>
<tr>
<th>Country</th>
<th>1911</th>
<th>1912</th>
<th>1913</th>
<th>1914</th>
<th>1915</th>
<th>1916</th>
<th>1917</th>
<th>1918</th>
<th>1919</th>
<th>1920</th>
<th>1921</th>
<th>1922</th>
<th>1923</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,390</td>
<td>2,379</td>
<td>1,902</td>
<td>743</td>
<td>841</td>
<td>1,315</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Denmark</td>
<td>230</td>
<td>146</td>
<td>156</td>
<td>170</td>
<td>121</td>
<td>146</td>
<td>123</td>
<td>77</td>
<td>60</td>
<td>141</td>
<td>135</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>1,285</td>
<td>2,079</td>
<td>2,341</td>
<td>3,179</td>
<td>2,634</td>
<td>3,451</td>
<td>1,411</td>
<td>1,803</td>
<td>861</td>
<td>1,182</td>
<td>1,921</td>
<td>1,924</td>
<td>1,924</td>
</tr>
<tr>
<td>Netherlands</td>
<td>913</td>
<td>655</td>
<td>439</td>
<td>563</td>
<td>281</td>
<td>243</td>
<td>292</td>
<td>170</td>
<td>135</td>
<td>151</td>
<td>267</td>
<td>596</td>
<td>596</td>
</tr>
</tbody>
</table>

1. Number of stables infected.

In Austria cases of animal anthrax numbered 10 in 1919, 38 in 1920, 68 in 1921, and 104 in 1922. In the Argentine Republic, 10,140 cases were reported in 1918, 4,132 in 1919, 813 in 1920, 1,123 in 1921, and 884 in 1922.

Canada has published no statistics; France reported 248 cases in 1918, 397 in 1919, 398 in 1920, 632 in 1921, and 549 in 1922; South Africa reported during 1921-1922, 292 infected localities in the Cape Provinces, 49 in Natal, 357 in the Orange Free State, 560 in the Transvaal, and 298 in Transkei. In Great Britain during the period 1911-1920, 6,550 cases were reported — an average of 635 a year; in 1921 the cases numbered 647. New Zealand has had no definite case since 1907, but in 1922 some suspected though not confirmed cases were reported from one farm. In Rumania animal anthrax seems fairly common, but details are wanting. In Sweden fatal cases numbered 847 for the period 1912-1914, 538 for 1915-1917, 229 for 1918-1920, and 225 for 1921-1922. Poland reported 288 cases during nine months of 1920, 912 in 1921, and 1,479 in 1922. Czechoslovakia gives the following figures for the provinces of Bohemia, Moravia and Silesia: 388 (1911), 498 (1912), 398 (1913), 332 (1914), 293 (1915), 214 (1916), 231 (1917), 210 (1918), 119 (1919), 144 (1920), 199 (1921), and 241 (1922).

In Italy, statistical returns contain from 1920 onward the number of stables infected, instead of the number of cases amongst animals. In 1924 the number of stables infected amounted to 1,504, in 1925 to 1,369, in 1926 to 1,634, and in 1927 to 2,532. The inspectorate is of opinion that the difference between the number of stables and that of the cases of infected animals is not in practice very great, for the animal is generally isolated and slaughtered and in consequence does not cause infection to spread to other animals in the stable and to the pasture.

The kind of animals most frequently attacked are oxen and sheep. As a matter of fact, of 10,258 anthrax-infected animals in Italy during the period 1915-1919, 5,702 were oxen and 4,336 sheep; of 3,747 in Czechoslovakia, 3,350 were oxen; and of 1,765 in France between 1918 and 1923, 1,139 were oxen and 590 sheep.

In Great Britain, 69 per cent. of the cases of anthrax among animals were said to be due to the importation of contaminated foodstuffs and fodder, 15 per cent. to infected soil, and 18 per cent. to causes unknown.

The statistics relating to human anthrax, so far as they are obtainable, are as follows:
Uruguay reported 186 (31 fatal) in 1923. ed 1 fatal case in 1919, 5 (3 fatal) in 1920,
to 1913; 12 (1 death) from 1916 to 1919;
Southern Russia, etc. the majority from Pennsylvania (22).

In Argentina 1 case was reported in 1911,
1912, 9 in 1913, 9 in 1914 to 1918, 1
in 1919, 11 (with 3 deaths) in 1921, 13 (with
1 death) in 1922, and 8 in 1923.

Denmark reported 44 cases from 1910 to
1918, 2 cases (both fatal) in 1920, 1 in 1921.
From the United States 89 cases (with
42 deaths) were reported in 1922, the
majority from Pennsylvania (22). During
the first quarter of 1924 31 cases were
reported (of which 12 occurred in the State
of Missouri). In New York State during
the period 1919-1923 61 cases (19 fatal) of
human anthrax were reported (of which
32 were caused by shaving brushes, 16 by
hides and skins and 42 by horsehair, etc.).

In Canada no cases have occurred in
Alberta, New Brunswick, Prince Edward
Island. In Nova Scotia 2 cases were
reported (1917-1919); in the Province of
Quebec 51 cases (1 fatal) between 1896 and
1917; in Ontario 23 cases (7 fatal) between
1882 and 1919, etc. In South Africa there
were 46 cases in 1921-1922 and 48 in 1922-
1923. France publishes no statistics for
agricultural anthrax but reported 200 cases
(25 fatal) of industrial origin from 1910 to
1913, 157 (19 fatal) from 1914 to 1919, 48
(5 fatal) in 1920, 21 (5 fatal) in 1921, and
17 (1 fatal) in 1922. In the Netherlands
cases of anthrax number about 50 a year.
Fatal cases have been: 1 in 1919; 3 in 1920,
1 in 1921, and 2 in 1922. Poland reported
45 cases (9 fatal) in 1920, 66 in 1921, and
56 (10 fatal) in 1922. In Roumania there
were 704 cases (62 fatal) in 1922. In Russia
the reported cases of anthrax numbered
3,904 in 1921 and 7,801 in 1923. The districts
most hit are the Ukraine, middle Volga,
Southern Russia, etc. Sweden shows the
following figures: 156 (4 fatal) from 1997
to 1913; 32 (1 death) from 1916 to 1919; 1
(fatal), in 1922-1923. Czechoslovakia returned
1 fatal case in 1919, 5 (3 fatal) in 1920,
49 (6 fatal) in 1921, and 81 (5 fatal) in 1922.
Uruguay reported 186 (81 fatal) in 1923.

In Italy, cases of anthrax notified amounted
to 2,205 in 1923, 2,728 in 1924, 2,989 in 1925, and 1,753 in 1926.
So far as occupational groups are concerned, agricultural anthrax affects
especially labourers, butchers, slaughter house hands, and veterinary surgeons.
In industry anthrax is most prominent (except in Great Britain) in the hides
and skins industry, after which comes that of horsehair and bristles. The statistics of
three great industrial countries give the following figures:

For Germany and Great Britain the most recent statistical data are as follows:

<table>
<thead>
<tr>
<th>Industry</th>
<th>Germany (1910-1921)</th>
<th>Great Britain (1910-1921)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hides and skins</td>
<td>95</td>
<td>78</td>
</tr>
<tr>
<td>Hair and bristles</td>
<td>39</td>
<td>38</td>
</tr>
<tr>
<td>Wool</td>
<td>1,700</td>
<td>1,017</td>
</tr>
<tr>
<td>Other industries</td>
<td>60</td>
<td>52</td>
</tr>
</tbody>
</table>

Note. — The raised figures refer to fatal cases. Very detailed particulars are given in the
articles dealing with the industries in question.
the upper limbs; twice on the lower limbs; twice on the back. Once only there occurred a case of internal anthrax.

External anthrax (malignant pustule) is the most frequent clinical form. Thus in France, of 431 symptoms 386 were malignant pustule, 38 anthracemia, 8 malignant pustule associated with anthracemia, and 4 internal.

External anthrax occurs most frequently on the head, the neck, and the upper arms. From statistics collected in France and Germany relating to 1,550 persons the pustule was situated on the head in 601 cases, on the neck in 219, on the upper arms in 630, on the legs in 36, and on the trunk in 42.

According to statistics of cases in Great Britain prepared by Legge, a relation can be made out between the mortality from anthrax infection, certain particular conditions of which time a general reaction takes place: a rise of temperature of the patient's surroundings, the general symptoms at first very ill-defined vertigo, somnolence, nausea, prostration, shivering, violent cramps in the chest, dyspnoea with violent oppression, etc., very often difficult to interpret. Then follow the signs of congestion and pulmonary oedema, dry frequent cough coming in spasms, or an atypical pneumonia with frothty,

A fatal issue ushered in by an exacerbation of the symptoms and hyperpyrexia, generally occurs on the ninth or tenth day, sometimes more rapidly. Recovery, rarely spontaneous, most frequently follows early intervention and shows itself in improvement in the local and general symptoms. In 90 per cent. of the cases the pustule is situated on the uncovered parts (face, neck), the position affecting moreover the seriousness of the lesion (more dangerous on the face).

Anthracemia (malignant oedema), which is less frequent, is usually situated on the eyelids, more rarely on the neck, arms, and thighs. It always begins with a diffuse painless oedema often extending widely. The condition develops much more rapidly and is more serious than malignant pustule and often leads to a fatal issue. Infection internally (pulmonary or digestive) gives rise to internal anthrax (pulmonary or intestinal) in which general infection dominates the clinical picture. In such cases diagnosis is difficult so that death often supervenes before anthrax has been even suspected by the medical man. Recently (1924) Sanarelli has said to have demonstrated the impossibility of the development of anthrax in the intestines. Research, therefore, was necessary to ascertain how internal anthrax could develop in animals and man. Sanarelli has shown that internal anthrax can be contracted through the respiratory tract. Anthrax spores coming in accidental contact with the buccal mucous membrane can easily pass into the lungs. If they are very numerous (a rare event) they set up anthrax pneumonia and death. But if they are scanty they are engulfed by phagocytes and, through the systemic circulation, are deposited in various organs. They remain there a long time in a latent condition, incapable of growth. Provided, however, that they are not digested by the cellular ferments the anthrax spores can at any moment give rise to a fatal anthrax infection, certain particular conditions only require to present themselves, as for example, a rise of temperature of the patient's surroundings, a diet poor in water, etc. Among spore carriers anthrax infection can be started by the injection of cytolytic substances like quinine, arsenic, lactic acid, and even distilled water.

Pulmonary anthrax commences with general symptoms at first very ill-defined vertigo, somnolence, nausea, prostration, shivering, violent cramps in the chest, dyspnoea with violent oppression, etc., very often difficult to interpret. Then follow the signs of congestion and pulmonary oedema, dry frequent cough coming in spasms, or an atypical pneumonia with frothty,
sometimes bloodstained, expectoration. Fever is absent or moderate accompanied by cyanosis. Death ensues with collapse and hyperpyrexia in the course of four or five days. Sometimes the form of the disease is fulminating.

Recovery is very rare. When it does occur convalescence is long with the possibility of relapse even after three months.

Gastro-intestinal anthrax is very rare, coming on acutely with symptoms generally analogous to those of a severe infective gastro-enteritis, colic, bloody diarrhoea, abdominal pains, irregular pulse, cyanosis, choleraic aspect, etc. Death occurs in from two to five days.

In accordance with recent experiments (1925) carried out by Sanarelli, the bacilli are quickly killed by the gastric juice and even by the intestinal juice. The spores pass through the stomach without undergoing change, but, contrary to the opinion of certain authors, conditions there do not favour their proliferation. It has been found in vitro and in vivo that anthrax spores do not develop there. On the basis of these experiments, Sanarelli is not inclined to admit the clinical picture of intestinal anthrax.

Like any severe infective condition anthrax exercises a baneful effect on the cardiac muscle, showing itself in a marked increase in the rapidity of the pulse — more remarkable in very severe cases. If the pulse frequency has a tendency to increase progressively the prognosis is bad.

In animals anthrax is generally intestinal, septicemogenic in character, without notable local phenomena. It is possible however to find in oxen of certain regions (America, India, China, Australia) a form of anthrax localised, at first, to the tonsils and attended by oedema of the glottis and suffocation (gargantilha or garottilha of South America). A real pustule analogous to that present in man is only found when the animal has been bitten by an insect on the most delicate part of the skin (udder, anus, etc.). This is the form known in Brazil under the name of Olho preto.

**Diagnosis**

The lesions are often so characteristic that the diagnosis of anthrax is easy, especially if the history and precise knowledge of the occupation come in to assist.
The necessity for bacteriological examination in the diagnosis of malignant pustule is apparent in doubtful cases and especially in internal anthrax where the diagnosis otherwise is very difficult and often impossible. Search for the bacillus should be made in the exudation from the pustule, in the expectoration in the pulmonary form, in the faeces in intestinal anthrax, and in culture from the blood. If agglutination has no value, search for the specific sensitiser can be helpful in diagnosis. The reaction of the precipitins of Ascott allows anthrax to be diagnosed in carcases dating some time back when the bacilli may have disappeared from the blood and viscera.

**Prophylaxis**

Intervention is necessary in every case, even when only suspected, without waiting for confirmation by laboratory diagnosis. A negative result does not permit of the conclusion that the case is not anthrax.

**A. Animal Anthrax**

The sources of animal anthrax may be in (1) soil foci (kept up by spores that have lived for a period more or less long in the pasture lands of infected localities), (2) water foci (that is, areas fed by spores carried with the effluent from factories manipulating infected raw materials).

The prevention of animal anthrax comprises a number of measures now accepted in the legislation of the majority of countries which have codified sanitary measures dealing with contagious disease among cattle:

1. Compulsory notification of cases suspected to be anthrax or diagnosed as such.

2. Isolation of affected animals and sometimes compulsory slaughter. Isolation of animals which have been in contact with sick or dead animals.

3. Destruction of the carcase without opening it (by burning or deep burial in quicklime); prohibition of the use of products emanating from animals that have died of anthrax.

4. Disinfection of infected localities and destruction of the dejecta. Campaign against insects which can have come into contact with sick animals or their secretions, carcases, etc.

5. Prohibition of the import of suspected animals or of those coming from suspected areas.

Several countries require by law compulsory vaccination and provide a free supply of vaccine or grant subsidies. Others indemnify the owners of slaughtered animals attacked by the disease. The indemnity in some countries is limited to half the value of the animal and is withheld if notification has not been made within the period specified by law.

**Vaccination.** — Toussaint was the first to realise the possibility of vaccination against anthrax, which Pasteur, assisted by Chamberland and Roux, made practicable in 1881. It is carried out by the two following methods:

(a) The Pasteur method rests on the principle of immunisation of one subject by inoculation of attenuated virus, giving rise to slight symptoms only and enabling the organism to resist a stronger virus or the different kinds of natural infection. This principle is attained by the use of two viruses, the one weak, the other strong. The Pasteur vaccines are made by culture at unfavourable temperatures but others are in use in which attenuation is obtained by heating or by the action of antiseptics or by chemical methods, or compressed oxygen (Chauveau).

(b) The second process of Cienkowsky (vaccination by immunising bodies containing the attenuated spores) is a modification of Pasteur's method. Two series of immunising bodies are used consisting of cultures much attenuated by the action of high temperatures. To obtain a constant virulence the test animal used is *spormophyllus cystilus* (souslik). A good supply of spores is obtained on killing the cultures, after the formation of the spores, with a solution of glycerinated serum added in such a way that the vaccine No. 1 is one-tenth of vaccine No. 2. The virulence of the two vaccines is such that 0.2 grm. of vaccine No. 1 kills the mouse and souslik and the same dose of vaccine No. 2 kills the guinea-pig, but not the rabbit. The advantage of this process lies in the stability of the immunising bodies used and the possibility of their dosage.

In other countries vaccines Nos. 1 and 2 are different in degree. Thus in Italy vaccine No. 1 kills mice and not guinea-pigs, while another kills mice and one or two out of five guinea-pigs. For vaccine No. 2 a vaccine may be used which kills 50 to 70 per cent. of the guinea-pigs and another 100 per cent. None of these vaccines otherwise is sufficiently virulent to kill rabbits or give a localised reaction at the point of inoculation.
Cienkowski's method was the one most used in Russia. From the information supplied the losses in the course of immunisation were said to be very limited (among horses from 0.1 to 0.3 per cent.; cattle from 0.02 to 0.07 per cent.; sheep from 0.1 per cent). The same is the case also in Hungary, where this method has been introduced quite recently — horses and oxen, 0.03 per cent.; sheep, 0.01 per cent.

Good results have also been obtained in North America and in Japan, where Cienkowski's method has entirely taken the place of Pasteur's. Vaccination to-day costs very little and gives a relatively lasting immunity. Nevertheless the immunity gradually lessens after several inoculations; hence necessity, generally disputed by those interested, of repeating the vaccination, so as to maintain resistance to infection.

Experience really shows that vaccination of flocks and herds ought to be practised at least every three or four months by repeating always inoculation of a double dose of vaccine No. 2. In Italy it is generally done every 6-12 months when it is a question of the usual livestock, and every 4 months with high-class animals and dairy cows.

Where vaccination has not been repeated, anthrax has sometimes occurred three months after the last inoculation. The procedure enables the animals to become resistant to more virulent vaccines fatal to rabbits and confers a great immunity to forms of very virulent vaccine. It gives, 1042 hours later, a third injection of a very virulent culture which is raised (41°-41.5°-42° C.), or if the animal shows signs of a grave general infection, recourse is had to high doses of serum intravenously (200 c.c.) because smaller doses, even if repeated at short intervals, are found to be insufficient.

Eight days after the first injection of serum (20 c.c.) in the case of sero-vaccination a second inoculation of vaccine is given, and 12 days later, both with vaccination and sero-vaccination, inoculation with serum No. 2 is done using a double dose of that ordinarily given (0.5 c.c.) in order to intensify the active immunity.

This method, as used in Italy, has never given rise to any accidents, and in comparison with other methods has given a stronger and more lasting immunisation.

**Immunisation by sero-vaccination** is a combination of active (vaccination) with passive (inoculation with serum) immunisation and has been popularised by Sobernheim. He uses anti-anthrax serum and a culture of anthrax bacilli the virulence of which is analogous to Pasteur's vaccine No. 2.

This method obviates all the objections to vaccination. After an injection of serum and vaccine Sobernheim gives 10-12 hours later, a third injection of a very virulent culture which gives the animal such a degree of active immunity as could never be obtained by other methods. This method, applied systematically during the war when hides and skins from foreign countries, used in tanneries, disseminated anthrax in a more fatal form than previously, has given really excellent results.

In conclusion, sero-vaccination alone is insufficient and expensive (in Italy the per animal of sero-vaccination is 0.60-70 L., while that of vaccination is 0.30 L.), but is useful during times of epizootic spread. The most serviceable preventive measure, therefore, seems to be vaccination.
B. Human Anthrax

Although treatment rests with the physician, the use of serum at the earliest period possible is not sufficiently insisted on even in suspicious cases and before any bacteriological examination has been made. The harmlessness of the method being recognised, with the object of insuring early intervention, premises in which there is risk of anthrax should make a point of seeing that a supply of serum is available for first-aid treatment. A slight expense of this kind will thus avoid delay in treatment, which otherwise might be fatal to the victim.

In every suspected case make a subcutaneous or intramuscular injection of 20-30 c.c. of serum at different points of the body if necessary. In a case of external anthrax (first stage) inject subcutaneously (abdomen or thigh) 40 c.c. of serum at intervals of 20-30 c.c. every 24 hours until there is improvement in the general condition or diminution of fever. In the most severe or late cases inject 40-50 c.c. in the muscles and 20 c.c. in the veins. Repeat the intravenous injections on the days following with doses of 10-20 c.c. (or intramuscularly of 10-30 c.c.) until there is noticeable diminution of the pulse. In cases of internal anthrax inject without any delay 20 c.c. of serum intravenously and 40-50 c.c. into the muscles. Repeat the intravenous injections at intervals of some hours until the danger is past. Apply caustic energetically to the pustule, put a bandage over the lesion and prescribe digitalis. Exclude absolutely anything in the nature of surgical interference which might help the spread of the bacilli in the organism.

The use of neosalvarsan proposed by F. Becker is now currently practised at the Pretoria hospital (South Africa). The anthrax patient receives an intravenous injection of neosalvarsan (0.6-0.9 grm.), the exact dose depending essentially on the state of the patient, being increased in proportion to the severity of the case. The injection is repeated next day; generally it is followed by a marked rise of the temperature. On the fourth day in certain very exceptional cases a third injection is given.

In the case of sick persons, or such as have been exposed to contagion, the measures followed might take the form of serotherapy with a view to cure, or of prophylaxis in the case of wounds, etc.; in the case of persons coming in contact with animals suspected to be suffering from anthrax, or which have contracted it, they would include protection of the hands and skin, exclusion of persons with skin lesions, disinfection of the hands with 2 in 1,000 dichloride of mercury and personal cleanliness.

For *industrial anthrax*: General measures would include (a) cleanliness, dust extraction, etc., disinfection of raw materials; (b) working clothes or overalls, caps, gloves, etc., personal cleanliness, etc.; (c) organisation of a health service; close medical supervision of those exposed to risk; notification of cases of anthrax, instruction to workers to repair immediately to the doctor or ambulance room in the case of skin lesions, however slight; (d) provision of first-aid requisites if there is no permanent ambulance staff; provision of antianthrax serum in premises exposed to risk of anthrax; (e) warning placard of the regulations in force.

The preventive measures in the case of human anthrax should cover the particular dangers in each industry: wool, hides and skins, horsehair and bristles, horns, hoofs, etc. (see these articles).

From the international standpoint prevention of anthrax among animals will ultimately be studied by the International Institute of Agriculture in Rome, which in this matter will keep in close touch with the International Labour Office. The problem of disinfection of hides and skins contaminated with the spores of anthrax has been confided to a mixed International Committee consisting of members of the Council of Hygiene of the League of Nations and of the International Labour Office—a Committee which will direct all the enquiries made in this direction in the various countries (laboratories and tanneries).

The question of disinfection of anthrax-infected wool having been dismissed by the International Labour Conference of 1924, any action taken must be limited for the time being to horsehair, hoofs, and horns. Details as to the problems to be solved will be found in the articles relating to the industries in question. Measures should be taken to protect transport workers and to provide adequate ambulance provision for dock labourers. For the protection of flocks and herds against anthrax, even before an International Convention is agreed to, it would be in the interests of agriculture and of the different States to engage in a more and more active campaign against animal anthrax.

Lastly, the attention of those concerned should be urgently directed to the
difficulties of diagnosing the disease and to the necessity of enabling doctors to acquire the necessary knowledge.

**Legislation**

Compulsory notification of animal anthrax has been required by legislation in most civilised countries: Germany (Law of 26 June 1909 and Regulations of 7 December 1911); Austria (Law on Epizootic Diseases of 29 February 1880); Denmark (Laws on Veterinary Police of 24 August 1894 and 14 April 1920); in South Australia, Tasmania, and Victoria by the laws on epizootic diseases; in the Argentine Republic by the Law 3,959 of 8 November 1906 (Veterinary Police); in Canada by the Law of 1906; in France by Article 29 of the Rural Code; in Great Britain by Order No. 7,939 of 1910 of the Ministry of Agriculture; in Italy by the Sanitary Law of 1917 and Veterinary Police System of 10 March 1914; Netherlands (Law of 26 March 1920); New South Wales (Law of 1901); Poland (1901-1909, formerly Austria); Queensland (Law of 1915); Rumania (Law of 20 November 1913); Sweden (Royal Decree of 9 December 1898 and Law of 1 May 1903); Switzerland (Federal Law of 13 July 1917 on Epizootic Diseases and Executive Order of 30 August 1920); Czechoslovakia (Law of 6 August 1909); Tasmania (10 June 1927); U. S. S. R. (Circular No. 214/390, dated 8 May 1924 and No. 396/460, dated 13 September 1924, on anthrax prevention).

Human anthrax is required to be notified:

(a) As an infectious disease: in Germany (Law of 30 June 1900 and Order of 28 November 1909); in the Argentine Republic (Decree of 1 April 1911); in Belgium since 1917; in Austria since 1907; Prussia, Baden, etc.; in Canada (Public Health Law); South Africa (Art. 18, Law of 1919, Regulations of 1923); Austria (Law of 14 April 1913); United States (in 25 States under 1906 Act and 1912 Act); Italy (Sanitary Regulations of 3 February 1901); Poland (25 July 1919); Rumania (Regulations of 8 December 1881, September 1894, June 1897, July 1905); Sweden (will be made at once obligatory); Czechoslovakia (Law of 14 April 1913); Uruguay (May 1916); Tasmania (10 June 1927).

(b) As an occupational disease: in Austria (Order of 1 August 1912); Argentine Republic (as an accident) by the Law 9,688 of 10 June 1927 and particularly by Art. 149 of the Regulations which gives the victim the right of compensation; South Australia and Victoria (1902); New Zealand (1905); Great Britain, not obligatory in agriculture but in industry under section 73 of the Factory and Workshop Act, 1901 (which does not apply to docks or the transport industry), but the local authorities can add anthrax to the diseases notifiable under the Infectious Diseases Notification Act; France (anthrax is not among the list of infectious diseases notifiable under the 1902 Act, nevertheless a Circular dated 20 July 1910 calls for notification of cases of industrial anthrax to the inspectors of factories and calls for a special enquiry in each case); India (Act of 5 March 1923, section 3 (2)); Netherlands (since 1905 by Art. 21 of the Law of 1911); Queensland (compulsory when the infection is contracted in the course of certain industrial operations, e.g. combing, wool-sorting, handling of skins, bristles, hairs, wool, carcasses of animals; in these cases the diseases are treated as occupational (Law of 1916-1921) and accident compensation is paid); Rumania, notifiable and treated as an accident (Law of 17 June 1916).

Generally the law regards industrial anthrax as an accident, and compensation is granted accordingly. In a number of countries, however, anthrax is included in the list of industrial diseases, giving a claim to compensation: South Africa, Alberta, South Australia, New Brunswick, British Columbia, Nova Scotia, Nova Scotia, New South Wales, Great Britain, India, Manitoba, Ontario, Queensland, New Zealand, Saskatchewan, Victoria, Western Australia, U. S. S. R., in Canada by Article 29 of Circular 214-390, dated 8 May 1924, and in the United States of America (Minnesota, New York, Ohio); lastly the Argentine Republic and Japan.

The Draft Convention on Occupational Diseases passed by the International Labour Conference at Geneva, 1925, contains in the list appended to the Convention infection from anthrax described in the following terms: "Anthrax infection: work in connection with animals infected with anthrax; handling of animal carcasses or parts of such carcasses including hides, hoofs and horns, loading and unloading or transport of merchandise."

**First-Aid Boxes.**—The French Decree of 9 October 1913 prescribes that the first-aid box should close easily and contain 30 grm. of tincture of iodine (official) in one bottle with a wide neck, closed by a ground glass vaselined stopper; a paint brush placed in a closed glass tube; two separate dressings, each dressing being kept in an impermeable and hermetically sealed envelope containing a gauze pad, a pledget of cotton wool, a strip of lint, a closed glass tube; two safety pins, the whole aseptic; two closed packets of 30 grm. of absorbent cotton wool; a strip of gauze 6 cm. wide and 2 m. long; a pair of nail scissors, and instructions.

**Placards.**—The French Decree of 9 October 1913 has drawn up a warning placard as to the dangers of anthrax infection. Similar placards have also been drawn up by the Medical Inspectors of Factories in Austria, Great Britain and the Netherlands, by the Health Officers in Germany, Belgium, Italy, etc., by private associations, such as those for the prevention of accidents, in France, Italy, Belgium, etc.

**Bibliography**

Antimony


Antimony is a metal of silver white colour with a bluish tinge; its structure is crystalline (rhombohedral) with a strong metallic lustre; its symbol is Sb, and density 6.85. It melts at 630° C. and volatilises at white heat (boiling point 1440° C.). It is very brittle and is easily pulverised.

At ordinary temperatures it is not affected by air, but becomes rapidly oxidised in the melted state. It burns with a bluish white flame without volatilising, but at about 900° C. gives off, in the presence of traces of oxygen, exhalations which have a smell resembling garlic, and dense white poisonous fumes.

It dissolves in boiling hydrochloric acid with liberation of hydrogen. Nitric acid changes it into oxide in the form of a yellowish white powder insoluble in water. It dissolves in aqua regia, from which it is precipitated by the addition of water in the form of a beautiful white deposit.

It is found occasionally in its native state (Sweden, Brazil, Mexico), but generally in the state of sulphide combinations the principal of which is stibine, Sb, S, or trisulphide of antimony. It is contained also in a great number of ores: sulphides of iron, copper, nickel, lead, silver, and in the form of metallic antimonides.

These ores are found especially in China, France, United States, Mexico, Australia, Asia Minor, Hungary, Japan, Portugal, Spain, Germany, Canada, Bolivia, Peru, Borneo, and Italy.

Compounds of antimony are very numerous. Those most used in industry are the trioxide, the chloride, the trichloride (tartrate of antimony and potassium), and the golden sulphide. All the oxides have the property of forming metallic antimony when heated to melting point at about 700-800° C. with cyanide of potassium.

Industrial Operations

The ore (stibine) is roasted in reverberatory furnaces where it becomes transformed into oxide (Sb, O₃) which, by calcining with charcoal, is then reduced to the metallic state. In the course of this process, fumes of antimony are formed (volatile dioxide of antimony) which should be recovered. Smelting of the ore in tall furnaces accomplishes simultaneously both roasting and reduction. Stibine can also be melted with iron (precipitation process), when the antimony which gathers upon the hearth of the furnace is collected.

In the electrolytic process a solution of sulpho-antimoniate of sodium (Sb, S, 3Na, S) is used in iron pans, fitted with iron cathodes and lead anodes. Antimony is deposited upon the cathodes, which are scraped with steel brushes.

Antimony obtained by these different processes is not pure and should be refined, which is effected by successive melting in the presence of nitrate and carbonate of soda. (See also articles "Lead" and "Silver").

Use

Antimony is used especially as an alloy with other metals and in parti-
cicular with lead, tin or copper, either with them singly or mixed. Arsenic (0.2 to 0.8 per cent.) and antimony (8 to 14 per cent.) are often added to alloys to harden them. Alloys with lead and tin are used for making type, antifriction metal, metal trimmings on furniture and decorative objects, in the pottery industry, some chemical products (colours), and in pharmacy.

**Toxic Action**

It is not yet clear if antimony is a cause of industrial poisoning, and the opinion of authorities on this point is particularly divided. Löwy, according to whom antimony, from the toxicological point of view, belongs to the same group as arsenic, supports Rambousek, Köelsch, and other experts in attributing any toxic action to arsenic, which is a frequent impurity of antimony. It is, therefore, sometimes difficult to know in any particular case if the poisoning is due to antimony or to arsenic. On the contrary, certain authors claim to have established by experiments (Boveri) or by clinical observation (Ferrannini, Scalia, Schrumpf, and Zadel) the toxic nature of antimony, while others do not consider the matter proven (Berterelli).

Seitz (1924) has reported among type-founders blood deterioration similar to that which he obtained experimentally with cats. A subcutaneous injection of antimony produced a diminution in the number of red and white blood cells (about 50 per cent.), whilst if the antimony was given by the stomach, a diminution of the white cells and an increase of the red cells were noticed. The results of experiments on guinea-pigs were not so pronounced. However that may be, medical literature reports instances of poisoning by antimony and Ramazzini was the first to describe the effects of antimony upon chemists.

It seems doubtful if all the compounds of antimony are injurious to the health of operatives who handle them; only the antimoniates and tartar emetic act differently both in regard to their local and general toxic effect. Whereas certain salts of antimony cause, when in large quantities, symptoms of poisoning, chronic poisoning by tartar emetic leads to serious degeneration of the internal organs without it being possible to explain this action.

In the chronic form brought on by certain antimonial preparations it is noticed, as distinct from arsenic, that there is not only a diminution of the white cells, but also in time, and with an increase of the doses, an increase in the relative and absolute strength of the absorption. It is not possible to obtain immunity against the local action of tartar emetic either by long administration of the substance or by preliminary treatment by salts of antimony or arsenic.

**Sources of Poisoning**

1. *In the course of manufacture* during the roasting of the ore, the great danger lies in the presence of arsenic, which exposes the workers to the absorption of this product and of its compounds, arsine oxide or arseniuretted hydrogen.

Some cases of poisoning have been observed among miners and smelters of stibnite (Biondi), especially when the working of the furnaces is defective, and during pulverising stibnite or pure antimony (Roth); and also among workers employed in putting into sacks the oxide drawn from condensing chambers, as well as among those employed in cleaning these chambers (Biondi and his pupils).

2. *In the course of its use*. Poisoning occurs, in the making of alloys as
well as of tartar emetic, from the inhalation of fumes of oxide of antimony (Erben). Lehmann is, however, inclined to think that the damage caused should be attributed to arsenic. The manufacture, as well as the manipulation, of type causes symptoms among the workers (smelthers, typesetters, etc.). These symptoms have up to the present been attributed to lead, but they may, on the other hand, be due to antimony (Schrumpf, Zabel). A. Hamilton, Carrozzi, and others, however, have not found any evidence of any special clinical entity attributable to antimony among hundreds of printers who were examined. Hamilton has only reported two cases of troublesome eczema of the hands and forearms among workers employed at the melting pots used for type.

Antimony in a finely divided state is used as "iron black" (noir de fer) for bronzing metal objects, colouring varnishes, glazing terra cotta, and preparing aniline colours (instead of arsenic).

3. In the course of other industrial processes. Fumes of antimony are set free in the lead industry during the reduction of oxides by charcoal (Patinson process of crystallisation); in zinc smelting, where the fumes may sometimes contain traces of arsenic, cadmium, lead or manganese; in copper and zinc refineries, where the fumes may contain other metallic impurities which cause dermatitis and an ulcerating rhinotrachitis, the former of which must be distinguished from the itching caused by copper and the latter from zinc asthma; in the desilvering of lead wherein risk occurs of poisoning by lead, arsenic and antimony during the roasting of ores; in electro-plating where the same danger as in the preceding case exists in the course of the electric deposition of gold, silver, copper, nickel, and zinc; in recasting old metal and scraps of metal, and in retrieving old rubber, due to setting free blue fumes of antimony during the crushing.

4. In the course of the use of its compounds. Hydrogen is set free during the burning of cannons, of rifles and steel objects by means of trichloride of antimony (Eulenberg, quoted by Lehmann). Hydrogen antimonide, like chloride of antimony, is not poisonous, but is very irritating. The golden sulphide is used to make antimony colours (bismuth, Cassel, and Naples yellow, cinnabar of antimony). The red (pentasulphide of antimony) and the yellow are used in the rubber industry. Although according to Carlson (Chicago), 8 per cent. of antimony in the red sulphide and 3 per cent. in the yellow sulphide are soluble in gastric juice, and are sufficient to cause injury to the workmen who use these mixtures in great quantities, yet industrial poisoning seems to be fairly rare (Hamilton). Further, it must not be forgotten that generally workers handle at the same time litharge and lead sulphate, so that the symptoms which arise are more probably to be attributed to lead. Other writers consider that the cases of dermatitis which have for a long time been attributed to antimony are for the most part due to the accelerators employed in vulcanisation (see article "Rubber").

For some time past it has been proposed to use oxide of antimony, either alone or mixed with zinc white, as a substitute for white lead. Sulphide of antimony is used in the painting trade as a mordant, and also for making the paste for safety matches. Tartar emetic and the fluorides of antimony are used in the dyeing of cotton and printing of cloth. Some cases have been recorded of local lesions caused by materials so dyed and used in the making of garments which are worn next to the skin (Kaysen, Sandtner). The trisulphide of antimony is used in the making of fireworks, and fulminating primers. According to an expert in the American artillery service, certain cases of poisoning reported during the war were possibly caused by antimony. Hamilton is of opinion that it is impossible to distinguish the effects of antimony from those of fulminate of mercury, as certain symptoms which have been noticed, e.g. local irritation of the skin and respiratory passages, are characteristic of fulminate.

**Symptoms**

Locally, antimony and its compounds cause very irritating eruptions of the skin, characterised by peculiar small pustules (eczema of antimony) which resembles those of smallpox, often accompanied by marked sweating.

Cases of keratitis have also been noticed, caused by the fumes of the chloride or trichloride of antimony; also cases of irritation with erosion of the mucous membrane of the mouth and throat; some of burning pains in the mouth and pharynx with swelling of the lips, the formation of vesicles, and increased salvation (Koelsch).

Acute poisoning which is very rare as an industrial disease has a symptomatology similar to that of arsenic, i.e.
cramp in the lower limbs, convulsions, and collapse.

Chronic poisoning, brought to light by Schrumpf and Zabel, is met with especially among workers exposed to dust containing antimony. It is characterised by a peculiar expression of the features, watering of the eyes, eczema, nervousness, irritability, insomnia, fatigue, vertigo, frontal and occipital headache, muscular pains, neuralgic pains in the extremities, nausea, vomiting, loss of appetite, constipation, intestinal colic, gastro-intestinal trouble of every kind, fatty hypertrophy of the liver, inflammation of the mouth and pharynx accompanied by burning sensations, bleeding from the nose and difficulty in swallowing. Stomatitis caused by antimony is not common; even though some inflammations of the mouth of mixed origin have been described, due to the association of antimony with lead or tin, it seems nevertheless that there is no reason for admitting that there is a stomatitis solely due to antimony. Symptomatology, of the stomatitis found does not differ at all from that of stomatitis caused by lead, arsenic, etc. But whilst in lead stomatitis the gumline is distinctly brown and often slaty-black, in that caused by antimony it has a special reddish brown colour tending to deep violet (Koelsch). Salivation is as abundant as with mercurial stomatitis. It should, moreover, be noted that alcohol and tobacco increase the effects of antimony. Thus Biondi has seen antimony smelters show a drunken gait after having drunk a glass of white wine or smoked a cigar.

Antimony causes a slighter anaemia than arsenic, but exceptionally it produces a serious anaemia and a secondary cachexia (Eulenberg, Scalia). Associated with this anaemia, variations of the blood picture have been reported, accompanied sometimes by complex and numerous morphological changes which depend on the susceptibility of the individual as well as on the duration and intensity of the poisoning. The blood changes in men affected with industrial poisoning agree with those obtained by laboratory research. In addition to the diminution in the number of red blood corpuscles (Scalia, Ferrannini), in their amount of haemoglobin and cytological strength (Ferrannini), and in the number of leucocytes (Schrumpf and Zabel, Scalia) and of blood platelets (Seitz), the appearance has been noticed of sudanophilic granules in the polymorphonuclears and the large mononuclears (Biondi and Galassi, Ferrannini), of eosinophilia often marked (Schrumpf and Zabel), of anisocytosis and polychromatosis and of polychromatophilia (Ferrannini), and also of a diminution in the alkalinity and the carbon dioxide in the blood.

In the serious cases there are cardio-renal changes with albuminuria, glycosuria, feeble heart action, lowering of blood pressure, giddiness, fainting, loss of strength, marasmus, and cachexia. Diminution of sexual desire, sensation of oppression, dyspnoea with cough and pains in the chest have also been reported (Löwy).

Antimony like arsenic may cause neuritis (recurrent and optic neuritis), difficulty of speech, athetotic movements, epileptic positions, melancholia, etc. (Löwy).

Unless they are very serious the symptoms rapidly disappear when the source of poisoning is removed. In the cases of Schrumpf and Zabel, the symptoms disappeared at the end of two or three weeks after suspension from work.

The diagnosis depends upon the medical history and knowledge of the trade of the person affected.

Detection

Antimony can be detected qualitatively in urine and faeces by means of Marsh's apparatus, or that of Naquet (reaction of antimonuretted hydrogen with silver nitrate), or even by precipitation by sulphuretted hydrogen. Antimony is detected in urine by the following reagent: antipyrine 1 grnn., iodide of potassium 2 grnn., water 30 c.c. After the destruction of organic matter the residue is dissolved in 1 or 2 c.c. of hydrochloric acid (at 1:5), it is filtered and then 0.5 c.c. of the nitrate is added to the reagent. If antimony is present there is formed a characteristic precipitate of a golden yellow. The investigation is sometimes carried out for arsenic and antimony at the same time. It is far from easy to effect detection, which is a matter for toxicologists.

Legislation

Generally speaking, regulations issued for the exclusion of women and young persons from metallurgical processes and processes preliminary thereto for ores containing lead, zinc, etc., are applicable also for the ores and smelting of antimony.

In Great Britain the regulations for the chemical industry of 11 July 1922 cover also the manufacture or the preparation of carbonates, chromates, chlorates, oxides and hydroxides of antimony.

The Greek law excludes boys of less than 16 years and young girls of less than 18 years from works dealing with antimony and its compounds.
Apothropine
(Atropamine)

This product is atropine with one molecule of water less (formula, C₃H₁₈NO, and is obtained as a secondary product of the mother liquor in the course of preparing atropine. It is obtained also by dehydrating sulphate of atropine by means of sulphuric acid or acetic anhydride.

Severe cutaneous eruptions, localised at first on the hands, are found in persons manufacturing apothropine. The lesion appears in the form of yellow ulcers which spread to all parts of the body. Marked conjunctivitis has also been described in a chemist who was in the workroom but not directly engaged in producing the substance.

In one case the dermatitis lasted for several months and the worser eventuallly had to be dismissed.

Arsenic (Poisoning by)
(Arsenicism)


Chemical Properties

Arsenic (As) is found in the natural state (native arsenic), although impure and with small quantities of iron, cobalt, antimony, silver and gold. But it is most often found combined with sulphur (red arsenic or realgar), As₂S₃; yellow arsenic or orpiment, As₂S₃; with iron sulphoarsenate of iron or mispickel, Fe₅As₅; with cobalt (sulphoarsenide of cobalt, CoS₃As); with nickel (nickelglance), Ni₃As₂. Some minerals, such as zinc, cobalt, copper, nickel, silver, iron and lead, contain arsenic among their impurities, and it can even be obtained as a secondary product by metallurgical treatment (in the form of arsenious anhydride).

The specific gravity of arsenic is 5.725 at 15°C. It is a good conductor of electricity. When heated to 450°C it gives off a vapour without melting at ordinary pressure (sublimation); under pressure it melts at 500°C. It emits a very characteristic allaceous smell. It dissolves in concentrated nitric acid, becoming converted into arsenic acid.

In dry air at ordinary temperatures arsenic undergoes no change, but it oxidises in moist air. At a temperature of 180°C, it burns with a bluish flame, giving off a smell like garlic and forming arsenious anhydride (As₂O₃). At high temperatures it combines directly with numerous elements.

Arsenic generally appears in crystalline forms of greyish white appearance, with a metallic lustre. There are three allotrop forms: a grey or black variety, which appears when arseniuretted hydrogen gas is heated: a dark brown variety obtained by reducing arsenic compounds; a yellow kind obtained by cooling ordinary arsenic by means of liquid air in the dark.

As a description will be given only of those compounds of arsenic of importance from the point of view of industrial hygiene.

Arsenicous anhydride (As₂O₃ or arsenic trioxide, white arsenic, arsenious acid) is a white solid substance occurring in the form of octahedral or prismatic crystals (in Claudetite) or in an amorphous or vitreous form. Its density is from 3.7 to 3.8. Only slightly soluble in water, it dissolves readily in acid or alkaline solutions.

The anhydride is found in nature; industrially it is obtained as a by-product from certain metallurgical processes. It is prepared on a large scale by roasting arsenical pyrites. The impure vapours are led along channels of masonry or are precipitated as a white powder (flowers or flour of arsenic) which is purified by sublimation into a transparent mass (arsenic glass).

Reduced easily to the state of arsenic, it oxidises just as readily, forming arsenic anhydride (As₂O₅), a white vitreous substance which dissolves slowly in water, becoming converted then into arsenic acid (As₂O₅HO). Heated with charcoal, arsenic anhydride is reduced to arsenic; at high temperatures it decomposes into oxygen and arsenious anhydride. (For arseniuretted hydrogen see that article.)

Arsenic acid (H₃AsO₃) is obtained in watery solution from the corresponding anhydride in the state of the salt.

Orpiment (arsenic trisulphide As₂S₃) can be obtained industrially by melting arsenious anhydride with sulphur. It still contains arsenious anhydride, and is therefore toxic.

Arsenic colours are represented principally by emerald green. Schweinfurth green (Cu₃(C₂H₃O₂)₃+Cu₂(As₂O₅)₁), which contains about 50 per cent. of arsenic and is very toxic, is an aceto-arsenate of copper. It is also known under trade names such as Patent green, Original green, Swiss green, Parrot green, Imperial green, Mitis green, etc. Scheele's green or Paris green (little employed) is an arsenite of copper (Cu₂As₂O₅) and contains about 52 per cent. of arsenious acid. Vienna green is an arseniate of
copper. Brunswick green is a mixture of Scheele's green, sulphate of lime, and hydrocarbonate of copper, etc.

These greens are now replaced for certain purposes by commercial arsenate of lead, which is a mixture of basic arsenate (As₂O₃). H₂O and hydrous arsenate of lead (PbH₂AsO₄). Formerly, it was made by reaction between the acetate and nitrate of lead and arseniate of soda; now replaced by the Luther Volck method — a reaction of lead oxide with a solution of arsenic acid together with a small quantity of nitric or acetic acid which acts as a catalyst.

By reducing the mono- and di-methyl arsenic acid by means of a zinc amalgam and hydrochloric acid, the primary and secondary arsines are obtained. The best known of the alkyl derivatives of arsenic are the cacodyl compounds, which are violent poisons. The aromatic arsentical compounds, it should be remembered, correspond with the nitrated nitric and aminoderivatives, as for example, arszenobenzene (see that article), etc.

**INDUSTRIAL OPERATIONS**

Arsenic is mainly obtained from mispickel (Fe₃As₂, arseno-pyrites) which, when heated in cast-metal retorts in the absence of air, gives off free arsenic which is sublimated and condensed in iron pipes. The preparation gives rise to arseniferous dust. Arsenic is also obtained from arsenic acid with charcoal.

The fumes given off in the course of the smelting operations at the Anaconda Copper Company of Montana (United States), consist mainly of arsenious oxide and sulphurous anhydride. As they pass through the piping they are deposited in the form of dust containing 20 per cent. of arsenic. The solid particles are precipitated by Cottrell's method and the dust thus recovered is sent to a second furnace, then through another Cottrell apparatus which yields a product containing from 75 to 90 per cent. of arsenious oxide that can be still further purified.

Schweinfurth green is obtained by mixing a boiling solution of copper acetate and arsenious-acid; the operation should be carried out in a closed vessel. Drying as well as sieving and barrelling must be done under a hood with locally-applied exhaust ventilation to remove the toxic fumes. The manufacture of this product, according to Hamilton, is the most important arsenic industry in the United States (Brooklyn and Chicago). As much as 0.093 grains of arsenical green per cubic metre have been found in workrooms where the salt is made.

It is very high incidence of tumour of the lung is, however, attributed to arsenic or arseniate of copper sulphate by arsenious acid in the presence of potassium. The preventive measures described above in regard to Schweinfurth green should be applied here also. Vienna green is made by precipitating copper sulphate in excess by means of arseniate of soda. Mitis green, used in painting, is an arseniate of copper.

**Uses**

Arsenic compounds are used in the chemical industry and preparation of various green colours. These are used (although in diminishing quantity) for painting, wallpapers, lampshades, playing cards, artificial flowers, toys, etc.; but it can be said that danger from this source is now chiefly of historical interest. These colours, on the other hand, are still used in dyeing. The arsenic compounds serve for mordanting, preservation of furs, feather and skins; stuffing animals; stripping hair from skins; manufacture of artificial stones, malachites and certain enamels; to decolourise glass and crystal; for black bronzing (arsenic sulphide) or green (copper arsenite); for preparing the "carrotting liquid" (Teleky); to destroy the larvae of mosquitoes (arsenic trichloride: United States), canker-worms, vegetable and animal parasites ("sheepdip") is a mixture of arsenic, flowers of sulphur, potassium carbonate and soap), etc. Arsenic is given off as compounds or arsenical vapours in the course of metallurgical processes with arseniferous minerals; in the melting of lead (the "fume", for example, and dust in the lead smelting works of Utah and Colorado contain more than 60 per cent. of arsenic), of silver, zinc, antimony, nickel, cobalt, iron, brass, in the manufacture and manipulation of sulphuric acid, hydrochloric and nitric acids; in galvanotechnical operations, etc.

**Sources of Danger**

Workmen engaged in the extraction of the metal run risk only of accident in the roadways. A very high incidence of tumour of the lung is, however, attributed to arsenic or arseniate of
cobalt (Schwarz, 1922) among the Schneeberg miners (see article "Cobalt"). Those employed in crushing and grinding are exposed to the risk of arsenic if the work is done dry or by hand. The roasted, sublimation, and raking of arsenious anhydride is particularly harmful.

Cases of arsenic poisoning have been reported among dock labourers in the Port of London (1912) employed in carrying birds' skins preserved with arsenical compounds; during the war among persons manufacturing arsenic trichloride (Great Britain), e.g. dermatitis and ulceration of the skin, especially of the face and hands, irritation of the mucous membranes of the nose, mouth and throat, etc., were reported; among chemists (lesion of the septum of the nose affecting an American chemist and his assistant, who during a period of six months had ground 10 to 15 kg. of trichloride of arsenic daily); among workmen handling birds' feathers; in glass factories (Ohio); among painters (Great Britain) handling paint in shipbuilding — in one instance one point; among lacquerers (use of lacquers containing arsenical compounds; the greatest damage occurred among American airmen scattering arsenic in the colours, liberating diethyl arseniuretted hydrogen gas). According to Biondi, the existence of arsenical green (Illinois), with irritation of the bronchial tubes, digestive disturbance, and ulceration of the intestines; among workmen handling arsenic acid. For practical purposes arsenic containing a certain proportion of the oxides should be considered as harmful.

The fatal dose of arsenious acid varies between one and twelve cg. (Lehmann). He concludes that one must be prepared for such effects as intolerance, acclimatisation, age, state of the digestive tract, the presence or absence of fatty matters in the food, etc.

When pure the sulphides of arsenic are insoluble and consequently are not toxic. But the commercial products always contain important proportions of arsenic acid.

Arseniuretted hydrogen gas is very toxic, an atmosphere of 1 per 4,000 being rapidly fatal (see article "Arseniuretted Hydrogen").

Arsenic in small or even in fairly large doses in people accustomed to it exerts its action especially on the haematopoietic organs (blood poisoning), giving rise to a hyperaemia which excites activity in these organs and those of the tissues. The bone marrow and perhaps also the other haematopoietic organs throw into the circulation a larger number of red blood corpuscles with some erythroblasts, which is evidence of medullary regeneration. According to the experiments of Bettmann, the blood changes set up by arsenic are not qualitative but exclusively quantitative. Sudanophil leucocytes have also been reported (Biondi); increase in the globular tension (by arseniuretted hydrogen: Giordano); increase of the coagulability of the blood (Silbermann and Heinz) and a slight increase of the viscosity of the blood (Farmachidis). Arseniuretted hydrogen gas, on the other hand, destroys the red cells and causes haemoglobinuria.

According to Biondi, the existence of arsenical erythrohaemia could not be sufficient to prove an embryonic effect and function of the haematopoetic organs. But the erythrohaemia, according to this authority, serves to explain why arsenic eaters can carry heavy weights without dyspnoea at high altitudes. The experiments of Delépine in 1922, following on an acute fatal case of poisoning by arsenic trichloride affecting a workman who had upset a vessel containing this substance over his leg, have shown that arsenic can be found in the hair and urine of persons and animals exposed to toxic vapours. Delépine attributed exclusively to the belief that the trichloride if applied to the skin could set up poisoning. The air of the workrooms where this product is prepared and handled may
arsenic poisoning, brought out the fact that one sample of coal contains 0.75 grm. of arsenious acid per kilogram and another 3.6 grm. Gifts, of Boston, had already enunciated the same view in 1891.

As to the action of arsenic compounds on the bladder, see article “Aniline”.

The localisation of arsenic is of great importance for the toxicologist; it must, however, be remembered that the data now available are anything but concordant on the point of the localisation of the poison in the different tissues of the body. Ludwig, for example, found, in the body of a man poisoned by arsenic, 0.00515 grm. in 100 grm. of kidney substance, 0.0038 grm. in 100 grm. liver, 0.0012 grm. in 100 grm. muscle, and 0.0004 grm. in 100 grm. brain. On the other hand, in a case of slow poisoning, Kohn-Abrest found on the whole in each organ analysed 1 mg. in the intestines and liver, 0.4 mg. in the kidneys, 5 mg. in the brain, and 0.1 mg. in the lungs, etc.

**Statistics**

Arsenical colours have set up dermatitis and poisoning especially in Germany. In a German arsenic factory the cases of illness presented themselves as follows:

<table>
<thead>
<tr>
<th>Years</th>
<th>Number of workers</th>
<th>Number of cases of Arsenicism</th>
<th>Number of cases of Arsenicism leading to Sickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1912</td>
<td>102</td>
<td>99</td>
<td>7</td>
</tr>
<tr>
<td>1914</td>
<td>91</td>
<td>71</td>
<td>4</td>
</tr>
<tr>
<td>1915</td>
<td>66</td>
<td>100</td>
<td>25</td>
</tr>
<tr>
<td>1916</td>
<td>118</td>
<td>302</td>
<td>39</td>
</tr>
<tr>
<td>1917</td>
<td>137</td>
<td>347</td>
<td>111</td>
</tr>
<tr>
<td>1918</td>
<td>148</td>
<td>248</td>
<td>56</td>
</tr>
</tbody>
</table>

The majority of cases were dermatitis and irritation of the mucous membrane (of the eyes, throat, and respiratory passages); there were also numerous cases of boils and ulcerations. During the period 1914-1918 14 cases of arsenic dermatitis were reported from Bavaria, of which 10 were due to Schweinfurth green; 5 cases due to Schweinfurth green occurred in 1921, 11 cases in 1922, besides 10 cases of dermatitis. Arsenate of soda was responsible for numerous cases of poisoning in a factory in Hanover which had taken up the manufacture without the necessary authorisation and without adopting the indispensable precautionary measures.

Finally, cases of poisoning from arseniac lead were reported in the United States among aviators engaged in scattering this substance in order to destroy parasites among vegetables.

In Great Britain the number of cases of poisoning by arsenic compounds contain appreciable traces of arsenical compounds.

The researches of certain experts (Bayet, Sloose, etc.) it should be recalled, serve to show that arsenic has a cancerogenetic action. In workmen coming into contact with pitch (see that article), suppurating lesions, warts, and cancers are frequently found; and samples of the coal examined by Bayet were all arseniferous to the extent of 1-5 mg. of arsenic per kilogram. Arsenic was also trace in the products of distillation such as the soot of the chimney, the ammoniacal effluent from the factory gas, the pitch, the oils, etc. Arsenic finally was found in the hair, the blood, and the urine of the workman employed (1921-1922). This view, however, is not accepted by some German and English authorities.

Biot, a Belgian medical inspector of factories, has determined the amount of arsenic in the different kinds of pitch used in the manufacture of patent fuel (1921). Of the 31 samples analysed, 17 coming from England contained from 10 to 130 mg. of arsenious oxide per kilogram of tar, 11 of Belgian source contained from 10 to 60 mg., while 3 of unknown origin contained only 10 to 30 mg. per kilogram (see article “Pitch”). The English view is that the arsenic present in the tar does not play a role in the production of epitheliomatous ulceration among tar and pitch workers.

According to the English pathologist, Jonathan Hutchinson (1887), small doses of arsenic acting for a long time may favour the development of epithelial neoplasms. Bland Sutton, Leuenberger, and others cite arsenic as one of the auxetic substances. Dubreuil, in 1910, described four cases of arsenical keratosi and collected 19 cases of epithelioma, but not one was of industrial origin; the three cases of Geyer (1900) were so only indirectly. On the other hand two industrial cases set up by the use of sheepdip have been described by Nutt, Beattie, and Pye Smith among 31 cases collected up to 1913.

The cause of soot pitch and paraffin cancer (see these articles and the article “Tumours”) has been closely studied, particularly cancer occurring among chimney sweeps, which generally is attributed to the arsenic present in the coal, chiefly English coal. It is due to this account that this morbid condition occurs more frequently in that country than on the Continent. The enquiry by Délépine carried out in 1903, to find an answer to the question set by the English Royal Commission on
Local Action

At the point where the caustic derivatives of arsenic are applied ulceration occurs; this is why the finger ends of workers who habitually handle arsenical compounds are specially selected as the site. The ulceration also becomes localised often at the angles and folds of the mouth and on the genital organs (carrying the caustic material thither by dirty hands).

Erosion of the septum of the nose is frequent. The dust coming into contact with the moist mucous membranes gives rise to arsenic acid which sets up well recognised ulcerations. The mucous membrane may be protected by pads soaked in iron hydroxide and magnesia oxide or by a mixture of camphor and petroleum menthol.

As regards cancerous lesions see above.

General Action

The different symptoms depend on the organs affected by the poison.

(a) Gastro-intestinal symptoms. — These are mainly vomiting and diarrhoea. Fits of vomiting follow habitual ingestion of the poison. They are intense and recur at each fresh ingestion of a liquid or solid. A large part of the poison is thus got rid of.

Diarrhoea also acts as a defence of the organism in eliminating the arsenic. It comes on some time after the commencement of the acute intoxication: abundant stools like those seen in cholera. In sub-acute cases the stools are yellowish and of foetid odour; diarrhoea may be absent in chronic forms.

These digestive troubles are accompanied by epigastric pain and colic, which is associated with the stools.

The gums at the same time become red and inflamed; sometimes erosions and even maxillary necrosis and loss of teeth, etc., occur. Pharyngitis and coryza are frequent.

(b) Skin eruptions. — These are frequent in the various forms of intoxication. But they take on different appearances. In the acute forms the eruption may be morbilliform, scarlatiniform or urticarial. Sometimes purpura is said to occur. Sometimes, too, the eruption may be papular, vesicular or pustular.

In the chronic forms, the skin is pigmented (melanoderma) — frequent in the Tyrolean arsenic eaters — on sites that are subject to friction (the neck, abdomen, and flexures). This pig-
mentation lasts long after the disappearance of the poisoning. Keratosis of the palms of the hands and soles of the feet is not uncommon; the nails and hair may fall out. A case of scleroderma is described by Ayres (1918).

(c) Kidney and heart affections. — These are less important than in mercury poisoning. For the most part they consist in diminutions of the quantity of urine passed, with presence of albumen lasting until death or until a cure has been effected. Certain terminal uraemic symptoms are said to appear in association with these symptoms in cases of slow poisoning.

The heart can be affected especially in acute cases; heart failure, lipothyramia, syncope even is not unknown (due to fatty degeneration of the heart muscle).

(d) Nervous symptoms. — Sensory nerve symptoms are characterised especially by severe headache and sometimes intense pains in the bones. In acute poisoning spasms of the sphincters occur as in cholera. Numbness, tingling and itching are extremely common. The painful anaesthesia of Mark should be borne in mind. Vision may also be affected: the patient complains of giddiness, failing vision (without obvious lesions of the fundus oculi), etc. Eczema of the eyelid, conjunctivitis (especially in susceptible persons) characterised by lachrymation, photophobia, with oedema but generally resulting in recovery; more rarely optic papillitis (case of Moleen, 1913; of Hass, 1919) with retinal oedema, diminution of sight, scotomas either relative for colours or absolute; arsenical lesions of the ocular muscles, ptosis, nyctagmus, etc., are rare.

Motor troubles consists of peripheral paralysis — toxic peripheral paralysis; generally they start in the lower limbs from whence progressively they proceed upwards. The paralysis is generally symmetrical and in one-half of the cases subsequently involves the upper limbs.

Tendon reflexes are abolished; the extensor muscles are particularly affected and a precocious atrophy is often marked. Anaesthesia remaining localised in the extremities accompanies it.

Such is the form seen in acute cases; the duration is usually short.

In chronic poisoning, on the other hand, the course is slow and sometimes takes on an incurable polyneuritic form localised in the small muscles of the hands and feet; tendinous retractions may develop, necessitating surgical interference.

The motor affections are rarely seen industrially. In Mark's statistics, which go as far back as 1891, they do not appear. Brouardel was the first to describe arsenical paralysis in a case of sub-acute industrial poisoning.

Clinical Form

The symptoms described show themselves more or less frequently and variously according to the amount of the poison, the channel of absorption, and the compound concerned. There are thus two distinct clinical types.

(a) Very acute form. — This is evidently exceptional industrially. It arises from massive ingestion of arsenic acid. Gastric symptoms are severe, vomiting incessant. The patient has a feeling of dryness in the mouth and thirst. After some hours diarrhoea supervenes, and death advances rapidly, the patient being pale, cyanosed and aneuric — the appearance closely resembling cholera.

(b) Acute form. — This is much the most frequent and that seen habitually in the majority of cases of suicide, accidents, and after medicinal doses. Occasionally it is seen industrially.

The necessary dose requires to be high and death usually supervenes six, eight or fifteen days after the accidental taking of the arsenic. But because of the early vomiting the poison may be rejected in part and a cure may follow.

Vomiting and diarrhoea, habitually very frequent, cease at the end of 24 to 48 hours. When this happens, improvement sets in with a feeling of well-being. Then a day or two the general condition becomes worse, the pulse small, the extremities cold, the patient cyanosed, breathing becomes laboured, the urine diminishes in quantity and is found to be loaded with albumen. Death follows in a state of syncope. It is important to recognise that this remission occurs in arsenical poisoning. It seems to be pretty general and it is after its appearance that the cutaneous lesions described show themselves.

If a cure takes place convalescence is long. The patient complains of gastrointestinal troubles. Chronic nephritis sets in, often also paralysis, and, even after a long time, fatal syncope may occur.

(c) Chronic form. — This is much the most frequent form industrially. It follows on daily doses of the poison,
sufficient to cause death, but sufficient to produce organic changes.

The first signs are more or less marked digestive troubles; salivation, vomiting, diarrhoea, and signs of paralysis in the lower limbs with sensations of numbness and tingling.

The patient also suffers from, though to a slighter degree, similar symptoms to those observed in acute poisoning — eruptions, paralysis. If the poisoning continues palmo-plantar keratosis will appear, as well as melanoderma.

But the symptoms may not all be present together; in some patients certain pathological symptoms predomi-

nate which in others are absent: the digestive troubles and paralysis seem to be the most frequent.

Finally, the cerebral symptoms must be referred to. These are almost all confined to the chronic cases: thus there is a toxic delirium, that is, mental confusion. In some cases Korsakoff’s syndrome or association of mental changes with symptoms of polyneuritis are present.

**Diagnosis**

Diagnosis has to be made in very different conditions according as whether the poisoning is acute or chronic, and whether in reference to a patient or in the case of an autopsy.

**Acute Poisoning**

In many cases knowledge of the possibility of poisoning helps much in diagnosing the case. Failing this diagnosis must be based on cumulative evidence as to agreement of the symp-
toms, remembering always that acute poisoning can appear in different forms and that some symptoms may be lacking; the most constant are the gastro-intestinal symptoms, eruptions, and nephritis.

In fatal cases often sanguineous effusions of the mucous membrane of the digestive tract are striking, by reason of fatty degeneration of the viscera with ecchymosis.

Here again search for arsenic often results in detecting it, since analytical methods, which have been brought to a high state of perfection, enable as little as one-hundredth of a milligram of arsenic to be found in a hundred grammes of viscera.

**Chronic Poisoning**

Diagnosis here is particularly delicate; but again knowledge of the poisoning (occupation in which arsenic of no

matter what kind is manipulated) allows certain diverse symptoms to be referred to their proper source. The possibility of an error in diagnosis should always be borne in mind in regard to cases where local ulcers are present round the corners of the mouth and on the genital organs (diagnostic from syphilitic ulcers).

Post-mortem diagnosis must be based on detection of arsenic in the viscera — but the presence of normal arsenic in the body must not be forgotten (this is only found in appreciable quantity in the thyroid and mammary glands) and the arsenic which may have entered the body after death (rain water in arseniferous localities): an analysis of the earth ought to be made at the same time. The possibility of the patient having been under medical arsenical treatment must also be taken into consideration.

**Demonstration**

This is work for the toxicologist, but it may be useful to refer to the subject in passing.

The reagents must be very pure: they are submitted therefore to a rigorous control before each research: acids must not contain more than one part in 10 mil-

lions of arsenic. In methods depending on hydrogen reliance must not be placed on the reaction of zinc on acid, as zinc always contains a little arsenic. The processes applied vary according as the arsenic is present in ponderable amounts or only in traces.

The first thing to do is to destroy the organic matter: this is done by heat and requires great precaution because arsenic is volatile and loss by evaporation is almost inevitable.

The best method of dosage consists in precipitating the arsenic as arsenic tri-
sulphide (As₂S₃) and weighing the precipitate. To destroy the organic matter the material is heated with hydrochloric acid and potassium chlorate. Thus the excess of chlorine is driven off by boiling. The residue is diluted with water and filtered. Hydrogen sulphide is next bubbled through the solution for three days: the precipitate of sulphide is filtered and dried. The precipitate and filter are then treated with sulphuric and nitric acid. Careful incineration follows. The carbon is removed with hot water and filtered and the filtrate is reduced by a current of sulphurous anhydride, which is elim-

inated next by boiling. The solution, after having been acidulated with hydrochloric acid, is again treated for three days with hydrogen sulphide, the excess being then driven off by a current of carbonic an-

hydride. The arsenic sulphide is filtered on a tared filter, washed and dried at a temperature of 110° C. and weighed.

The only impurities which can be present in the precipitate are copper and
mercury. They are removed, if present, in the following way: the precipitate is dissolved in sulphide of sodium or sulphide of ammonium if mercury is present. Filtration follows and arsenic passes into the solution. If this filtrate is acidulated with hydrochloric acid, arsenic trisulphide is reprecipitated. Saturation with hydrogen sulphide follows in order to complete the precipitation: filtration on a tared filter follows and washing with water containing hydrogen sulphide, alcohol, ether and carbon bisulphide. The operation is completed by fresh washing with ether and drying (S. Roche Lynch, 1922).

Thorpe's method resembles Marsh's, differing only in that the arseniuretted hydrogen gas is produced by electrolysis of the arsenical solution in a special apparatus.

This apparatus has been criticised by many because the platinum electrodes are said to lose their sensitiveness.

The Gutzeit method or its modifications is also recommended. With this method electrolytic hydrogen has to be used. All the same Marsh's method is to be preferred.

The Reinsch method is purely qualitative; it is an excellent means of ascertaining the presence of arsenic and ought always to be used. Its sensitiveness is somewhere between the gravimetric methods and those of Marsh and Gutzeit. The Reinsch method requires only two reagents: hydrochloric acid and copper leaf.

Heim and Hébert have proposed the use of the method recommended by them for the demonstration of antimony (see that article).

Kohn-Abrest uses the following method: about one gramme of dust is treated with dilute nitric acid; evaporation to dryness follows in a bain marie; some ten decigrams of magnesia and some cubic centimetres of a 20 per cent. aqueous solution of nitrate of magnesia are added; evaporation and calcination to a dark red then follows. The resulting ash is treated with dilute sulphuric acid and introduced into the Marsh apparatus.

It has been suggested to substitute for the Marsh method microscopical examination of the crystalline bodies formed with silver nitrate, magnesia liquor and the molybdic reagent with arsenic compounds. This last method is the most delicate for revealing arsenic in the form of arsenic acid; sensitiveness equals 1/20,000 of a milligram (Piutti and Boggio-Lera, 1922).

**HYGIENE**

The floor of the workrooms should be of cement so as to ensure impermeability; the passage ways should be paved and capable of being flushed with water.

The workroom should be well ventilated; large hoods should be placed over apparatus and connected up with a chimney with good draught; the poisonous fumes should be absorbed by passage through coke wetted with nitric acid. Every toxic emanation should be condensed and any dust caught removed. Complete airtightness must be ensured by use of cover for piping and entire apparatus for dust removal. In factories for the manufacture of compounds of arsenic hot processes should be done under glass hoods and manipulation of powders in glass cabinets hermetically closed. Protection of the workers against dusts of arsenical greens, especially the very light Scheele's green, which flies about readily, is very difficult to secure. Automatic packing is not possible and the ordinary means of protection (e.g. by respirators) favour sweating and consequently ulceration of the skin. Persons with moist skin and those who sweat readily are unsuitable subjects for the work and should be excluded.

In an American factory A. Hamilton found 0.093 grm. of arsenic per cubic metre of air.

The effluent waters should be neutralised before being led to a drain or sewer (see article "Hides and Skins"). Care should be taken as to how the rain water that has come into contact with material or dust, etc., containing arsenic is disposed of.

Mechanical and automatic methods should take the place of hand labour. Apparatus and receptacles require to be very strong to avoid breakage. In all operations where arsenic dust is likely to arise, the tables on which the work is done should be provided with downward exhaust ventilation. Special working clothes and head-gear, washing accommodation with hot and cold water and towels to enable the workers to wash face and hands before meals and before leaving work should be provided.

Neither food nor alcoholic drinks should be allowed in the workroom and smoking and snuff-taking should be prohibited.

**LEGISLATION**

Employment of women is forbidden in any room where arsenic is found free in the air unless workpeople are prohibited from introducing food into these rooms and unless a good potable water is supplied to them: Canada (Alberta and Ontario). In the manufacture of arsenic acid by means of arsenious acid and nitric acid; in the manufacture of arseniate of potassium by means of salpetre, and in the manufacture of arsenic sulphide: France. Wherever arsenious dust, fumes or gas are evolved: Japan. In the manufacture of arsenic and its compounds,
in that of verdigris (Spanish green), in the preparation of certain products having regard to their delivery or use: Netherlands, Russia, etc.

Employment is prohibited in the case of young persons under 14 years of age in Belgium in calico printing generally, in the manufacture of wallpaper, waxed taffetas or varnished cloth, in colour printing on cloth, and in workrooms where coatings or materials containing toxic substances are prepared, under 15 years in Delaware in the manufacturing or packing of colours and the manufacture or use of toxic dyes; in Japan in works manipulating arsenic or its compounds and in workrooms where arsenical dust, fume or gas is evolved; in Italy, in the case of boys under 15 years of age in factories where colours or materials containing arsenic are made, in the manufacture of arsenical alloys, in the smelting of ores containing arsenic (calcinatory chambers, etc.), and above all of arsenical copper, and in paper factories where colours containing toxic dyes are prepared for impregnating wallpapers are used: young persons of less than 16 years in all the States of North America in which the manufacture and packing of lead colours is prohibited (prohibition applies also in the case of the manufacture or packing of arsenical colours and manufacture and use of toxic dyes: Alabama, California, Connecticut, Maryland, New Jersey, North Dakota, Oklahoma, Pennsylvania, Wisconsin); in the manufacture and use of poisonous dyes in Argentina; in Belgium in the manufacture of arsenical compounds; in currying leather; in workrooms in which skins are treated with lime and sulphide of arsenic; in Canada (Quebec) in the manufacture of arsenical white; in packing colours and Scheele's green; in Greece in factories for the preparation of arsenic and its compounds; in Spain in the painting and decorating of toys, calico printing when arsenical colours are used, and the manufacture of arsenic and arsenical preparations of arsenic and arsenious acids; young persons of less than 18 years in the Netherlands as also of women; in South Africa in grinding colours; in France in the industry of painted cloth and workrooms in which poisonous substances are used; in Switzerland, etc.

Employment of female young persons under 18 years of age is prohibited in Canada (Quebec); in Greece, together with boys under 16; under 21 years of age in Belgium and in Spain as in the case of young boys under 15, and in Italy and in the case of boys of less than 15; for young persons under 18 in Switzerland, etc.

In France the Decree of 1 October 1913, as to the special precautions to be taken in factories for the manufacture of emerald green, known as Schweinfurth green, (arsenic-arsenide of copper), prescribes frequent washing of the floors and walls of workrooms, where solution of the product and the precipitation and filtering of the same is done, as well as washing of external walls of the vats and other vessels used for the process. They must also be kept constantly moist. Vessels in which the material is brought or placed are covered or closed under ventilating hoods. The drying of the green is to be done in a stove hermetically closed except for ventilating pipes. Workers are forbidden to enter rooms where the product is processed before it has cooled. Means for personal protection (respirators, moist sponges, cloth gloves, powdered t alc of Fuller's earth, working clothes, etc.) are to be placed at the disposal of the workers and the washing of these frequently effected by the management.

In Great Britain the Chemical Regulations of 11 July 1922 (No. 731) apply to all operations involving the manufacture or extraction of chromates, oxides and hydroxides of arsenic, arsenic acid and arsenious anhydrides. (For details see articles "Chrome", "Chromates", "Nitro and Amido Derivatives").

In Western Australia the Factory Act, amended in 1923, controls the factories in which compounds of lead, mercury and arsenic, are prepared and manipulated. The Government has the power to prescribe the conditions under which periodical medical examination shall be made in these industries.

In Illinois the Act of 1911 and in Missouri that of 1915 prescribe the same measures in factories for the manufacture of arseniate of lead and Scheele's green as for white lead.

In the Netherlands the factories for compounds of arsenic giving off fume are subjected to the same measures as those laid down in the case of fumes of mercury, and factories evolving dust to the same regulations as those applied in the case of white lead.

Production of arsenic compounds is included in the Russian Regulations of 10 April 1922 on industrial safety, which prohibits young persons of both sexes and women from this industry, regulates the length of the working days and lays down the precautionary measures to be taken as regards lighting, heating, ventilation, protective devices, sanitary and medical treatment, washing and cloak room accommodation, accident prevention, etc.

Use of arsenic in the printing trade, dyeworks, etc., is forbidden or regulated by the Order dated 19 September 1924.

Poisoning by arsenic and its compounds is compulsorily notifiable in the Grand Duchy of Baden, in Bavaria, France, Great Britain, Western Australia, Poland, Russia, Saxony, and the U.S.A. (California, Connecticut, Maine, Maryland, Michigan, Mississippi, Missouri, New Hampshire, Pennsylvania and Wisconsin). In the Netherlands notification is obligatory for cases reported in the following industries: glass-works, chemical works and chemical laboratories; industries for making, altering or repairing ladies' hats; artificial flowers; manufacture of waxed cloth; stuffing of animals; shot factories; wallpaper factories; sheep and wool washing places; dyeing, printing and bleaching of stuffs; weaving; tapestry; and coal mining.
Poisoning by arsenic and its compounds is brought within the Workmen's Compensation Acts in the following countries: Argentina, Australia (Queensland, South Australia, Victoria, and Western Australia), Bolivia, Brazil, Canada (Alberta, British Columbia, New Brunswick, Manitoba, Nova Scotia, and Ontario), Finland, Germany, Great Britain, Japan, New Zealand, Switzerland, and the U.S.A. (Illinois, Minnesota, New Jersey, New York and Ohio; in New Jersey and Illinois the products covered are arsenic lead and Paris green, as well as poisonous dusts and poisonous chemical products).

**Prof. Ballhazard**

(Paris).

**Arseniuretted Hydrogen**

French: Hydrogène arséné (Arsine). —

**Properties**

Arseniuretted hydrogen (formula AsH₃) is a gas which cannot be obtained directly by the combination of its elements, but is chiefly formed from arsenical compounds when they come into contact with nascent hydrogen; in this case it is diluted with hydrogen. It is obtained in the pure state when sodium arsenide reacts with dilute sulphuric acid.

A litre of arsieniuretted hydrogen weighs 3.49 grm.; so that this gas is heavier than air. It liquefies at -40° C. and even at -110° C. it does not solidify. It has an extremely unpleasant smell like garlic, but in strong concentrations the smell is absent (Koelsch, Jaeger). It is neutral in reaction, and very unstable; its formation is accompanied by a considerable absorption of heat; it is easily decomposed into its constituent parts, either by heat or an electric spark, and explodes when acted upon by fulminate of mercury.

It is not readily soluble in water, five parts of which only dissolve one part of arsieniuretted hydrogen, or in alcohol or ether; but it is very easily dissolved in oil of turpentine and much less easily in pure fat oils. These chemical properties explain its action on living protoplasm (Zangger).

In the presence of a sufficient quantity of air, arsieniuretted hydrogen burns with a pale flame giving off water and arsine anhydride. Without a sufficient quantity of air, or if the flame is cooled, there is a deposit of black arsenic powder. It is absorbed and completely decomposed by a solution of silver nitrate, especially if a little nitric acid is added.

**Sources of Poisoning**

Arseniuretted hydrogen is very little used in industrial technique. It is used in chemical laboratories for separating arsenic after the volatilisation of arsieniuretted hydrogen; in medico-legal investigations; at chemistry lectures when preparing the gas for the purposes of demonstration; in researches on aniline dyes and arsenical compounds. The persons exposed to the poison are thus chemists, physicians, physiologists, and medico-legal specialists (Glaister, Zangger).

It must be borne in mind that the dark-coloured deposit observed when arsenic is deposited after the volatilisation of the arsieniuretted hydrogen is either arsenic or sulphide of arsenic, and this also applies to the brown deposit which is noticed when the flame is directed on to a cold china saucer (Zangger).

Arseniuretted hydrogen is liberated chiefly as a by-product in the course of certain industrial operations when hydrogen is formed in the presence of traces of arsenic in either metals or acids, which react on each other; whether it is the metals or the acids which contain these traces of arsenic or both together, the result is the same. Hydrogen when generated contains arsieniuretted hydrogen, for metallic ores, as well as some metals in the raw state, often contain considerable quantities of arsenic. This is why industrial sulphuric acid contains arsenious acid from 0.001 to 0.014 per cent., and commercial hydrochloric acid contains it from 0.0014 to 0.691 per cent.

Zangger points out that the presence of antimony facilitates the production of arsieniuretted anhydride and also that, as long as this substance is being liberated, no antimonious hydrogen is produced. The production may be accelerated by the addition of salts of copper or platinum.

Arseniuretted hydrogen may be given off in the course of a few operations carried out in the chemical and metallurgical industries.

Some of these operations are enumerated below.

**Chemical Industry**

There may be noted in the chemical industry all those factories which manufacture or make use of sulphuric acid, produced from arseniferous ores (pyrites); and those which utilise or manufacture hydrochloric acid, manufactured from arseniferous sul-
Phosphoric acid. Here the cleaning out of acid tanks is particularly dangerous; and cases of poisoning have been reported by Legge. Arseniuretted hydrogen is also given off: in the course of treating lyes with sulphuric acid; in the manufacture of artificial soda; in the preparation of chlorine by Deacon's process; in the preparation of hypochlorite of lime, of chloride of phosphorus, of the chloride and sulphate of zinc (1 case reported by Bannister), of chloride of methyl, of dimethylsulphate, of guncotton, of sulphate of iron (from scrap iron), etc.; in the manufacture of cement when treating the "sediment" (Bodensatz) with sulphuric acid; in all aqueous electrolytic reactions, for recent research has shown the constituents contain arsenic which with hydrogen becomes volatile; moreover, small quantities of oxide of arsenic may be transformed into arseniuretted hydrogen; arseniuretted hydrogen is also given off when sulphuric acid is used in electric batteries composed of bichromate of potassium, or in charging accumulators. Hot sulphuric acid contains traces of arsenic; this danger is especially connected with submarine accumulators (cases mentioned by Giordano, Belli, Dudley); during galvanising in an arsene bath and in numerous processes of organic chemistry; in the manufacture of aniline dyes, due to the use of arsenious acid as a reducing agent; in the manufacture of rosiniline, and of fuchsine by oxidising an aniline mixture of ortho- and para-toluidine ("rotol") by means of arsenic acid; during the manufacture of glucose in the treatment of fecula with sulphuric acid; during the treatment of such ferment residues in soda and glucose factories, etc. It is also found as an impurity of acetylene and as such causes frequent attacks of illness especially when it is generated in a confined space.

Poisoning by arseniuretted hydrogen, known by the name of the "gulf disease" or "Haff disease", which in 1924 attacked the fishermen of Frisches Haff, a lagoon on the coast of East Prussia, deserves special mention. Long and searching enquiries carried out on the spot made it necessary before it was possible to make an etiological diagnosis of the disease.

Bacteriological, epidemiological and toxicological experts established a series of facts which made it possible from the start to put on one side the supposition that the epidemic was an infectious disease. Clinically, it concerned an apyretic disease, without enlargement of the spleen and non-contagious; cultures from the blood and urine were negative; and no parasites were found in the blood or faeces. The possibility of poisoning by food could also be excluded, for the families of the fishermen were not affected. Only persons exposed to the morning mist while washing nets and seeking bait on the shore, or who had disturbed the mud of the gulf were attacked by the disease. In the first place it always affected the fishermen whose work with lines or crab pots caused them to lean over the surface of the water; on the other hand passengers crossing the gulf were only very rarely affected, or persons who bathed there, or even those who navigated the boats, or the net fishermen who use boats with higher sides.

Further, the part of the gulf attacked varied according to the direction of the wind, which led to the conclusion that the disease was due to a poison emanating from the gulf itself.

The fishermen blamed the sulphurous waste from two large cellulose factories, which discharged their waste waters with the sewage of Königsberg. It was also noticed that since the war, the gulf was often contaminated in an unusual manner during the summer of 1924, forming quite close to the surface of the water, in enormous masses and often in a purifying condition.

Investigations made by Lewin in the factories in question elicited the following very important facts: in order to prepare the sulphuric acid required for making cellulose, they used up to 1924 Norwegian pyrites which did not contain arsenic. By contrast, Spanish pyrites which, starting from the said year, replaced the Norwegian pyrites, contained 0.3 mg. of arsenic per 1 kg. of arsenic. Waste water analysed by Gay contained 28 mg. of arsenic per litre, or 56 kg. of arsenic for the 2,000 tons of waste discharged daily.

The hypothesis that this arsenic, transformed by the vegetation of the gulf into arsiniuretted hydrogen, could cause the poisoning found among the fishermen is open to the following objection: the factories had before the war used Spanish pyrites without causing any evil effects. But another factor which had recently come into play supplied the solution of the problem. The construction of a dyke in 1916 at the mouth of the most important river flowing into the gulf had resulted in the transformation of what had hitherto been practically fresh water into water very similar to sea water — which further was continuously polluted by the 30,000 cubic m. of sewage water discharged daily by the town of Königsberg. This change in the water, formerly used as drinking water but
since rendered totally unfit for any domestic purpose, explains why the arsenical waste in 1924 underwent checks that the fresh water before the war could not cause. As a matter of fact it is known that salt water facilitates the production of arseniuretted hydrogen.

The substitution for the arsenical pyrites of pyrites weak in arsenic and the establishment of a passage allowing again the access of fresh water into the gulf soon removed the cause. As a result no case of the illness has been reported for several months (1925) (see also article "Hides and Skins").

In the same way volatile arsenical compounds, and arseniuretted hydrogen in particular, arise from arsenical manures, due to the action of fungi, e.g. Penicillium breviculae, as well as from substances containing oxides of arsenic (Zangger).

It must finally be pointed out that ferrosilicon which always contains traces of phosphorus and arsenic, decomposes in moist air with the formation of arseniuretted hydrogen and phosphoarsenic hydrogen (see article "Ferrosilicon").

**Metallurgic Industry**

Arseniuretted hydrogen is set free during the extraction of arsenic by roasting such arseniferous ores as mispickel or arsenical sulphide of iron; when roasting ores of cobalt and manufacturing cobalt blue; when fusing zinc ores, as well as during work with arseniferous zinc; during the manufacture of all combinations with zinc, with crude sulphuric and hydrochloric acids; during treatment with hydrochloric acid of arseniferous or arsenical sulphide of iron; during the galvanic bath containing sulphate of iron, and concentrated sulphuric or nitric acids; during the reduction of sulphides of arsenic; from electrolysis of arsenious solutions; and from the action of water or dilute acids on metallic arsenides.

Further, it may be set free during soldering due to arsenical impurities in the composition of solder or in the cleansing solution, or to dissolution of zinc in the hydrochloric acid; during corroding or cleansing metals by impure acids; during burnishing silver in imitation of old silver; during the galvanic precipitation of arsenic on unpolished articles in solutions containing arsenic (4 per cent.), antimony, green vitriol and concentrated hydrochloric acid; during plating or blackening silver objects by means of an acid arsenical bath containing sulphate of iron, and concentrated sulphuric or nitric acids, the reaction of which is accelerated by the addition of a few pieces of zinc (the process of Bayer quoted by Koelsch); during the bronzing of metals by immersion in nitric acid containing arsenic; during the cleaning of jewelery by impure hydrogen.

In conclusion it may be said that arseniuretted hydrogen is always about during industrial operations which give off impure hydrogen. In order that hydrogen may be chemically pure it must be prepared by the electrolytic process.

The above explains why poisonings are reported during the manufacture of hydrogen from zinc and hydrochloric or sulphuric acids for filling toy balloons and airships, and during the preparation of explosive gas, and of gas used for the oxyhydrogen blowpipe, etc. Out of 59 cases of poisoning reported by Rambousek, 11 were due to filling toy balloons, 3 to military balloons, and 13 occurred among chemists.

These cases of poisoning arise in consequence either of the presence of arseniuretted hydrogen in the hydrogen, or in consequence of the action on metals containing arsenic of an excess of hydrogen (Zangger).

The frequency of the liberation of arseniuretted hydrogen is explained by the fact that arseniuretted hydrogen can arise from the reduction of arsenious and arsenic acids and their salts by means of nascent hydrogen in an acid or alkaline medium; from the reduction of sulphides of arsenic; from electrolysis of arsenious solutions; and from the action of water or dilute acids on metallic arsenides.

**Toxic Action**

Arseniuretted hydrogen enters the body by the respiratory passages with air contaminated by the gas.
It is very poisonous in all concentrations. According to Zangger it is so in a dilution of 1 in 100,000, but after an absorption of long duration.

According to Erben a few puffs are sufficient to cause death. Schindler obtained symptoms of poisoning with quantities of gas corresponding to a strength of arsenic of 0.01 gmm.

Dubitzki, by means of experiments on animals, found that arsenuresetted hydrogen is 10 to 20 times more poisonous than carbon monoxide, sudden death certainly occurring with a dose of from 7 to 10 mg. of poison per kilo of animal. Doses from 2 to 9 mg. to 4.2 per kilo were tolerated, but it seems that about 5 mg. per kilo of animal represents the minimum fatal dose. If these figures are applied to man, the fatal dose will be 0.3 gmm. (66.1 c.c. of arsenuresetted hydrogen — Koelsch). Jochimoglou, in his researches on the haemolytic action of this poison, has fixed 0.1 gmm. to 0.15 gmm. as the fatal dose for man, whilst Wignall considers that stronger doses are necessary. Lehmann considers that a dose of arsenuresetted hydrogen corresponding to 0.01 gmm. of arsenic represents the smallest toxic quantity. (Schindler has seen a case of poisoning with this dose.)

But it must be admitted that the concentrations encountered in practice rarely reach these figures, which is no doubt due to the great instability of these products. In the case of the death of a chemist named Brittan, the fatal issue supervened after the absorption of 381 c.c. of impure hydrogen, made with arseniferous sulphuric acid, which represented 0.776 gmm. of arsenious anhydride (As2O3) or 0.612 gmm. arsenuresetted hydrogen. In another case, quoted by Taylor, death occurred at the end of six days after the inhalation of 150 c.c. or 0.7 gmm. arsenious acid. In the fatal case of Professor Gehlen (quoted by Loewy) death was caused by a dose corresponding to 0.55 mg. of arsenic. On the other hand, Rambousek has seen a serious case of poisoning arise after the inhalation of a hundreth of a milligram.

It is certain that concentration plays an important part. Dubitzki considers as dangerous a strength of arsenuresetted hydrogen of 0.05 per thousand.

The time spent in the contaminated air is sufficiently long, 0.03 per thousand suffices to cause trouble. According to Jochimoglou, a strength of 0.2 to 0.12 c.c. (0.94 to 0.38 mg.) per litre of air causes in the case of cats serious symptoms at the end of an hour’s inhalation; concentrations below 0.1 c.c. cause serious haematuria.

Hebert and Heim found that with mammals breathing an atmosphere containing 3.5 per thousand of arsenuresetted hydrogen caused in some instances general and fatal poisoning; a stay of a quarter of an hour, repeated three times at intervals of twenty-four hours, in an atmosphere containing 0.05 per thousand of poison, caused equally fatal poisoning, through successive doses. The sensitiveness of birds is still greater; the minimum general toxic dose is for them 0.09 per thousand and the dose when taken successively 0.02.

After absorption by the respiratory passages, arsenuresetted hydrogen passes through the lungs without causing damage; but it is not clearly known what this poison becomes in the body. It is probable that a very great part of it is expired, but it is equally possible that, by phenomena of oxidation, it becomes transformed into arsenious acid and that there is a system of storage in the tissues and organs.

Zangger points out that the action of this poison is quickly over, and that in the body it disintegrates quite rapidly into less poisonous products. According to Hamilton, the elimination of arsenic is very slow.

Arsenuresetted hydrogen is above all a blood poison, a powerful haemolytic agent; but it does not involve the formation of methaemoglobin. The haemolytic action is moreover not finished when the poison leaves the blood. Certain corpuscles are destroyed immediately, others have their life shortened; which explains the progressive decrease in the amount of haemoglobin found on the days following the poisoning.

Lehmann and Dubitzki think that the action on the blood is not always the only or chief one.

The poison as a matter of fact acts on the central nervous and peripheral systems (see later).

**Statistics**

**Great Britain.** — The cases of poisoning notified to the Chief Inspector of Factories were from 1900 to 1918, 53, classified as follows: chemical industry, 28; galvanising, 7; bronzing of metals, 5; dyeing operations, 4; other operations, 9.

From 1920 to 1924 inclusive, 14 cases were reported, of which 6 were fatal, classified as follows: 1920, 5 (of which 3 were fatal); 1921, 1 (fatal); 1922, 4 (of which 2 were fatal); 1924, 3; 1925, 2 (of which 1 was fatal); 1926, 1.

Dudley reports 30 cases of poisoning among a submarine crew, due to corrosion of lead plates in the accumulators by sulphuric acid containing 0.2 per cent, of arsenic.
Glaister in 1908 collected reports on 127 cases of poisoning by arsениуретті hydrogen, as follows:

Chemical operations in laboratories 30
Industrial operations 73
Military aeronautics 16
Wallpapers 6
Unknown etiology 2

Germany. — In the factories at Breslau the factory inspectors observed in 1902, 5 cases of poisoning, of which were fatal. In fifteen years Bachfeld has only seen a dozen cases, of which only one was fatal.

Koelsch in 1920 reported 130 cases of which 36 (27.7 per cent.) were fatal. He deals first with 11 cases (one of which was fatal), which occurred in 1915 in metallurgy during the making of vanadium steel, owing to washing arseniferous ores with sulphuric acid; then with 3 cases reported in 1916 by the Industrial Association (Chemische Berufsgenossenschaft), and with 116 cases reported in 1918 by Heffter and distributed as follows:

Laboratories 14
Chemical and metallurgical industries 64
Aeronautical industry 29
Making of toy balloons 16

According to the reports of factory inspectors cases of arsenical poisoning for the period 1920-1924 occurred in the following industries: in the manufacture of metal articles in galvanising (one case, very rare, was that of a workman operated in colouring a grey steel colour some iron ash bins lined with brass; the ash bins were plunged into a mordant made up of 1 per cent. arsenic, 2 per cent. hydrochloric acid, sulphate of iron and water; precipitation of arsenic occurred when a small stick of zinc was plunged into the mordant, the action of the acid on the zinc liberated hydrogen which combined with arsenic); in a copper foundry at Hamburg; in the district of Wiesbaden during the reduction of a nitrated compound by zinc powder in an alkaline solution; in Bavaria, affecting a person occupied in pouring sulphuric acid into a zinc bucket, etc.

In 1911, Dubitzki could only find 53 serious cases in laboratories, of which 16 were fatal. It is certain that slight cases must be much more common.

In 1914 Prößs reported 39 cases, of which 19 were fatal in 3 to 24 days, classified as follows:

Chemists 12
Filling toy balloons 17
Aniline workers 7
Lead industry 5
Aeronautics 3
Unknown etiology 1

In 1939, 12 cases reported at the Institute of Industrial Diseases at Milan originated in workshops for galvanising and photo-engraving.

The mortality is fairly high, but it is not as high as is ordinarily accepted. Heffter found a mortality of 28.4 per cent. (33 deaths in 116 cases); Geigl, 30.18 per cent. (16 deaths in 53 cases); Bachfeld, 8.3 per cent. (1 death in 12 cases); Koelsch, 9.1 per cent. (1 death in 11 cases), and 27.7 per cent. (36 deaths in 130 cases); Rambousek, 63.3 per cent. (19 deaths in 30 cases); and Glaister, 31.3 per cent. (37 deaths in 118 cases).

Symptoms

The early symptoms are due to anoxaemia, and the later ones to the presence in the blood stream and in the circulatory system of the products of the disintegration of red cells.

In very slight cases, there is simply lassitude, cephalalgia and malaise, sometimes a little dyspnoea and sometimes fainting; but generally work is very little interrupted, or not at all. There is a weak, quick pulse, a fall in arterial pressure, sometimes a yellowish coloration of the skin with the presence of arsenic in the urine (5 cases reported by Wignall).

In average poisoning cases, some hours after the inhalation (4 to 6 hours, Legge; 9 hours, Kunze-Krause) are noted lassitude, vertigo, shivering, syncope; the tongue is furred; there is oppression, heaviness in the gastric region, sometimes distress, nausea, vomiting, gastric, renal or hepatic pains and diarrhoea. Haemoglobinuria appears at the end of 4 to 6 hours; the urine is reddish brown, and for several days, contains blood and bile pigments. At the end of two to three days jaundice appears.

In serious cases, the onset is as in the preceding: the feeling of malaise which occurs at the onset increases in a few hours (three hours generally). There are shivering, fatigue, cephalalgia, pains in the hepatic and epigastric regions, dryness in the throat and thirst; kidney tenderness, breath smelling of garlic, hiccup, bilious vomiting which is sometimes blood-stained; a dull feeling of weakness, somnolence, semi-unconsciousness, giddiness accompanied by restlessness and insomnia; pulse rapid, weak, and regular at first, then feeble and thready; cardiac weakness revealing itself by diminution of the sounds of the heart; palpitations, and syncope; pronounced dyspnoea with cyanosis; haemorrhagic and congested conjunctivae; contracted pupils, slow to react; increased respiration (24 a minute); exaggeration of reflexes (foot clonus), muscular and nervous pains in the upper and lower limbs.

After eight to twelve hours haemolysis supervenes as well as haemoglobinuria.
The urine is blood-stained, and contains dissolved haemoglobin, hyaline casts, filaments of haemoglobin, and "shadow corpuscles." The urine is thick, slightly acid and contains albumen; it becomes very small in quantity, until the oliguria may develop into complete anuria, accompanied by pains in the kidney area.

Towards the second day a severe jaundice of the skin and mucous membranes makes its appearance of a coppery bronze colour, due to a mixture of the yellow colour of jaundice and that of cyanosis. On palpation the liver, and sometimes also the gall bladder, is found swollen and enlarged, signs of hyperactivity of the organ overburdened with its duty of destroying haemoglobin set free by haemolysis. The formation of bile is increased as much as up to twenty times the normal quantity. The spleen is also perceptible.

As regards the kidneys, there is sometimes a blocking of the urinary canalici by cellular debris, which explains the oliguria passing on to anuria. At the same time deep-seated changes take place in the structure of the protoplasm of the parenchymatous elements of the kidney. In some cases they may be nearly completely destroyed, only a small cellular focus remaining intact; it is from this focus that the complete regeneration of these organs is carried out (Zangger). Apart from these lesions, more ordinary symptoms may occur — for example, inflammation — which sometimes persist for a long time during convalescence.

The pathological conditions observed are then connected directly or indirectly with the effects of the poison on the blood.

Haemoglobinaemia brings in its wake jaundice and haematuria. Other troubles arise from the action of cell debris thrown off into the system. The kidneys and liver are overpowered by the increase of work, which elimination of the products of destruction of the blood cells necessitates. This in particular explains the increase in bile, which can no longer be excreted and invades the liver. The jaundice is definitely haemo-hepatogenous.

The blood picture is interesting: diminution in the number of red blood cells and of the haemoglobin index. In a week three-quarters or four-fifths of the cells are destroyed. Their number may fall to one and a half, or two millions, at the same time as the haemoglobin index diminishes from 16 to 20 per cent. (Koelsch). "Shadow corpuscles" appear. According to Hamilton baphile granulations, poikilocytosis, and anisocytosis are found. The blood is of a dark colour and laked; its alkalinity is diminished. Anisocytosis can, however, be considered as a sign of tumultuous regeneration rather than the index of a toxic condition (Biondi).

In addition to these lesions, there are to be detected signs of regeneration of the red blood cells which, as a matter of fact, go on for several weeks after the end of the poisoning; and also the presence of erythroblasts, of nucleated cells, of polychromatophiles, and of granulobasophiles. The myeloblasts are more numerous than the normoblasts. There is an increase in the thrombocytes.

A myelogenic reaction is also found with a modification of the leucocyte count. Hyperleucocytosis exists without there being any parallelism with the intensity of the poisoning. Whilst generally there is an increase in the number of neutrophile leucocytes, it may be said, from the point of view of the various groups of leucocytes, that there are individual reactions.

In one fatal case studied by Délépine the autopsy showed hypertrophy of the liver, which was in a state of fatty degeneration, the tissues adjacent to the big vessels being strongly coloured black from altered blood pigment. Under the microscope the hypertrophied tissue appeared in great measure to be atrophied and pigmented with necrosed areas. The kidneys were also hypertrophied, with commencing necrosis of the epithelium.

Clinical course. — In very slight cases, cure is effected in a few days.

In medium cases, the disease follows a favourable course and the symptoms subside. The blood and bile pigments disappear from the urine, but troublesome albuminuria persists and convalescence is fairly long, and strength is only slowly regained.

In serious, but not fatal, cases, convalescence occurs very slowly. More often than not the symptoms get worse; there is great weakness, dyspnoea, cyanosis, multiple haemorrhages, clonic spasms, unconsciousness, delirium, coma, and oedema. The pulse, hard at the onset, becomes quick and small; respiration slows; hiccup appears; and death occurs towards the second or third day at earliest, at the end of a week generally. The patients retain consciousness generally up to the end, although in the final period unconsciousness may occur with or without delirium. Sometimes death occurs more slowly; a case has been recorded of death on the thirtieth day (Koelsch)
which was due to anaemia (Bachfeld),
to action on the nervous system,
uraemia, and to cardiac failure.

In general, acute poisoning by
massive dose — such as is met with
in the manufacture of arseniuretted
hydrogen as a war poison gas — death
occurs rapidly without haemolysis
having time to show itself.

In very acute, and immediately fatal,
cases, the original cause of death is
haemoglobin and consequent cellular
asphyxia: in cases which are not
immediately fatal, death arises from
lesions of such organs as kidneys and
liver (secondary cause of death).

In serious cases when death does not
occur, sequelae may appear, the effects
of the poison on the nervous system
making themselves felt in various ways
and chiefly in the acute period.

An early sensitiveness of the nerves
which should not be confused with
polyneuritis, disappears in five to six
or eight cases on after an
interval; it depends on the toxic effects
of arsenic making themselves felt when
the poisonous arsenical albuminoid
combinations are decomposed (Zangger).
Toxic polyneuritis in some cases
develops two to four weeks after the
poisoning; it is shown by pains in the
nerves, especially in the extrem-
ities and between the ribs. A diminu-
tion of sensibility is also noticed, but no
motor disturbances. This polyneuritis
disappears in seven to ten days and
the patient returns to a state of health,
but slowly.

A typical picture of poisoning by
arseniuretted hydrogen was drawn in
1924 among the fishermen of Frisches
Haff, characterised by a special haemo-
globinuria. During the late hours of
the night, or the early hours of the
morning, after their work, at a time
when the fishermen lived in the lagoon, the fishermen were attacked by
a feeling of malaise and stiffness in the
joints. A little later a crisis developed
with full intensity: muscular pains
affected the neck, back, and loins, and
so severe that they fixed the patient in
absolute immobility, most often in his
boat, incapable of the slightest move-
ment for hours and even days until
someone came to his assistance.

The pains were often accompanied by
dyspnoea, cold extremities, and sweats.
Following retention of urine, at first
defeated unfruitful passing of a brown and
even black urine, which contained
haemoglobin, methaemoglobin and uro-
bilin, with four to five per cent. of
albumen and an abundant sediment,
made up chiefly of casts of haemoglobin.
The pulse was rapid and feeble, then

it slowed; the temperature was normal;
spleen not increased in size; mentality,
reflexes, and cutaneous sensibility re-
mained unaltered. The muscular pains
disappeared at the end of twelve to
twenty-four hours; the urine gradually
became clearer, but the albuminuria
often remained for two to three weeks.

Some atypical cases had myalgias
without haemoglobinuria, or haemo-
globinuria without myalgias.

The mortality was very low; for out
of 450 fishermen affected from the last
days of July up to the middle of
November 1924, 6 died. Four of the
fatal cases, however, occurred in sub-
jects who had incurable organic dis-
eses.

The fishermen who had been affected
once seemed more liable to fresh attacks,
as many as eight successive attacks
being observed; each time the attacks
developed in similar circumstances.

Chronic poisoning is a doubtful ques-
tion. If it exists, it does not give rise
to specific symptoms; but repeated, from
day to day it causes a chronic patho-
logical condition, perverting the physi-
ological functions of the blood-forming
system. Workmen, and more especially
chemists, who are exposed to chronic
inhalation, apart from the occurrence
of definite haemolysis, generally ex-
perience lassitude and an overpowering
sense of fatigue, without depressing
influences and loss of energy from
other causes entering into account.
Cardiac palpitation on the least exer-
tion is also noticed, the cause of which
may be sought in a whole series of other
causes. As headaches often occur,
"anticephalics" are prescribed sys-
tematically. In other cases there may be
cardiac instability, or digestive troubles
with anorexia and sometimes diarrhoea.

In these different cases it should be
noted that anaemia is not very pro-
mocious, apart from the occurrence
when the blood picture, however,
shows signs of regeneration, but not
very definite.

**Prognosis**

The prognosis of acute poisoning
depends first and foremost on the pre-
sence of oliguria; it is bad when the
quantity of urine passed diminishes.
Apart from lack of oxygen and asphyxia
of the tissues, consideration must be
paid to the part played by uraemia, to
decrease in the activity of the renal
functions, and to invasion of the blood
by urinary products.

**Diagnosis**

A positive diagnosis should be based
on the chief signs at the onset: cephal-
algis, weakness, nausea, vomiting, and blood-stained urine, appearing suddenly. The presence of jaundice confirms the diagnosis. However, at the onset of slight or average cases, which are the most important cases in practical industry, it is fairly difficult to make a diagnosis and it is necessary to eliminate gastric catarrh and catarhal jaundice.

In the most marked cases the absence of methaemoglobin enables a distinction to be made between acute poisoning due to nitro-compounds, such as nitrobenzene, which forms methaemoglobin, and to amido-compounds with their marked cyanosis. In poisoning by chloride of calcium, there is no jaundice. Poisoning by aniline is characterised by a livid colour, by methaemoglobin in the urine, and the absence of jaundice.

However, jaundice and haemoglobinuria are met with in a certain number of poisonings, and it is necessary to exclude all toxic haemalytics; the inorganic, e.g. Iyes of soda and potash, alkaline carbonates, and chloride of calcium; the organic, e.g. alcohols, ether, glycerine, Soaps, and cynamide of iodine; the animal, e.g. biliary salts and snake poisons; the vegetable, e.g. saponin, menthol, acconitine and piincoline; the animal, e.g. biliary salts and antimony; the organic, e.g. antimony and iodine; the animal, e.g. biliary salts and antimony; the vegetable, e.g. saponin, menthol, acconitine and piincoline; the animal, e.g. biliary salts and antimony.

Arseniuretted hydrogen, on the other hand, is the only one which is gaseous and capable of developing, at the expense of methaemoglobin. There is no jaundice, but all these poisonous substances must be absorbed per os, or penetrate by a break in the skin or mucous membranes. Arseniuretted hydrogen, on the other hand, is the only one which is gaseous and capable of developing, at the expense of methaemoglobin.

In addition, arsenic was found in the urine of patients (0.1 mg. per litre), in the stools (0.001 mg. per 5 grm. of stools) and even in the blood (0.05 mg. per 7 grm. of blood).

It must, however, be added that further researches (1926) of Matheis on the sequelae of the disease, of Meerwein on the water of the gulf, the air and gases of the schtanmi (mud), or Rohde, who experimented on animals, of Selter and Palewka on the sewage water, and finally pathological anatomical researches of Kaiserling, have not been able to confirm the results stated above, nor to justify the acceptance that the epidemic was due to arsenical poisoning; so the etiology of the disease of the gulf, according to these experts, still awaits solution.

**DETECTION**

This gas having a smell of garlic, the tendency is to consider that when this smell does not exist, arseniuretted hydrogen is not present. But recent work and a certain number of instances show, on the one hand, that the garlic smell is a poisonous substance, such as ethylarsine and diethylarsine, exist which have a smell of garlic (Biginnelli, Kunz-Krause, Arnold, Kober), and that, on the other hand, poisoning may occur without arseniuretted hydrogen being perceptible by its smell. Heffer thinks that the smell disappears in strong and fatal concentrations, and, as a matter of fact, Jaeger reported, in 1925, 41 cases of poisoning, of which 19 were fatal, in connection with which no odour was present. He must then be concluded that no relation exists between the concentration of arseniuretted hydrogen and the diminution of the garlic smell; that this poison in its nascent state is quite inodorous, and that the garlic smell is due to a change in the arseniuretted hydrogen which contains derivatives analogous to ethylarsine. The pure product is no less toxic than its derivatives, but the danger it presents is increased by the absence of smell.

Hebert and Heim have established a method of detecting arseniuretted hydrogen and have constructed a "hydr arseniometer", which depends on a yellow colour reaction between the poisonous gas and mercuric chloride. As a preliminary the gas for analysis is made to pass into a hydrochloric solution of cuprous chloride at 15 per cent. with the object of eliminating sulphuretted, phosphoretted and ammonium hydrogen, which may accompany arseniuretted hydrogen. The gas is then passed into a tube containing test papers soaked in mercuric chloride at 5 per cent. which turns yellow under the influence of the poisonous gas. The paper prepared beforehand can be kept in small strips, which only require to be slightly moistened by some drops of water at the time of using. The reaction is sensitive at 1 in 100,000.
These same writers advise also placing in workshops small birds, whose sensitivity to the poison is such that they can play the part of indicators just as they can in the case of carbon monoxide. In any case they are poisoned by doses which are harmless to man.

The quantitative method of Dubitzki utilises as absorbent materials silver nitrate, hydriodic acid, or chloride of calcium.

The test for arsenic in urine can be carried out by means of Marsh’s apparatus. (For the method of Gosio see the footnote on page 170.)

**Prophylaxis**

**First aid.**—In case of acute poisoning, the earliest etiological indication is to ward off asphyxia by administering oxygen under pressure; by blood transfusion; by bleeding and injecting physiological serum or Ringer’s solution; and by giving heart tonics and liquids which encourage diuresis.

Of course any liberation of arseniuretted hydrogen must be avoided.

When employing commercial hydrogen, Wentzki’s method of purification should be used. The hydrogen is passed through a cylinder containing a mixture of two parts of dry chloride of lime and one part of moist sand; it gives off any arseniuretted hydrogen and takes up a little chlorine which is retained in its turn by slaked lime.

In operations involving the liberation of hydrogen, only materials which are free from traces of arsenic should be used, or at least a preliminary examination should be made of their strength in arsenic. The strength of arseniuretted hydrogen in the atmosphere depends on the strength of arsenic in the raw materials, on the quickness of the reaction, on the quantity of the materials brought into contact with each other, on the cubic capacity of the place where the operation is carried on, and on the frequency and intensity of the ventilation.

Sight must never be lost of the possible liberation of arseniuretted hydrogen during certain operations which should be carried on either in closed apparatus, or in apparatus provided with a good exhaust.

Coal can also be a cause of arsenical poisoning.

Further, good general ventilation is needed; notably of places where ferrosilicon is stored. Dry warehousing prevents the development of vapours and poisonous gases.

Workers should be instructed in the dangers to which they may be exposed.

**Legislation**

The Regulations laid down for poisonous gases are applicable (see that article). In Prussia the Ministerial Ordinance of 5 October 1887 (revised 22 October 1902 and 8 January 1921) draws attention to danger from liberation of arseniuretted hydrogen. A series of instructions have been prepared by the Industrial Association of the Chemical Industry (1 January 1912).

Injuries caused by arseniuretted hydrogen are subject to compulsory notification in the State of Missouri, U.S.A. (see article “Gas and Fumes”), and in the Netherlands. Compensation is provided by the legislatures which compensate for poisoning by poisonous gases and is included in the schedule drawn up by the British Government, in the British Dominions where the law provides for cases of poisoning by arsenical compounds, and in Switzerland. Acute cases are generally treated everywhere as accidents.

**Bibliography**


For literature dealing with gulf or Half disease, see the *Bibliography of Industrial Hygiene* published quarterly by the *International Labour Office*.

Prof. H. Zanger (Zurich).
Artificial Flowers

BIBLIOGRAPHY


Artificial Flowers


Under this name are comprised artificial flowers, leaves, and fruit used for decoration, for funeral wreaths for trimming ladies’ hats, for wearing in the hair and on ball dresses, etc.

The raw material for this industry is silk, cotton, paper, gold beaters’ skin, celluloid and other artificial substances. For making up the flowers, caoutchouc or waxed cloth, glue (glues with a para basis dissolved in acetone, benzol, etc., in the rubber industry), starch paste, cotton, seeds, pistils, etc. The hearts of the flowers are made of cotton covered with rubber solution and dusted with coloured powders. The woman worker fixes in the pistil and petals with glue, covers the stalk with a tube, and mounts the little bouquet by means of very thin wire.

SOURCES OF RISK

The work is generally done in the workers’ homes or in badly lighted, overcrowded workrooms. It demands exercise of the small muscles of the hand and fingers, and continuous visual effort. The affections met with are in general the result of the sedentary life, the confinement, and work prolonged into the evening.

The diseases cited by various authors (skin diseases and lead and arsenic poisoning) are certainly of less frequent occurrence to-day than in the past. Besides cases of anaemia, chlorosis, dyspepsia, and tuberculosis, a fairly high incidence of cases of lead poisoning, due to the use of lead chromates, white lead (handling lead patterns and flowers dusted with lead colours), cases of arsenical poisoning (from use of arsenical colours, particularly green) characterised by cutaneous eruptions,
and general symptoms of poisoning have been reported. It is well known that fuschin was formerly prepared by the arsenical method, with the result that the colour was always contaminated by arsenic, whence the frequent cases of arsenical poisoning. Cases of mercurial poisoning were found to be of rarer occurrence.

Amongst other products which may injure the workers' health may be cited picric acid, which imparts a yellowish colour to the nails, methyl alcohol used to dissolve aniline colours (risk either in course of dipping or of drying; in an American factory an analysis of the air showed two parts in weight of methyl alcohol in 10,000 parts of air), celluloid (burning accidents), poisonous gases, glues (risk from their solvents), etc.

The authors who have dealt with this question report likewise cases of spasm of the fingers, of paralysis (due to lead poisoning from lead chromate). conjunctivitis, dermatitis, due to methyl alcohol, irritation of the mucous membrane (eyes, throat, etc.) due to silicon dust. Vernois met with thinness of the epidermis of the palm of the hand amongst women engaged in making up bouquets, and he found that they also suffered from redness and hyperaesthesia of the inner surface of the top joint of the thumb and index finger which was often the seat of a psoriasis-like eruption.

According to Hirsch, flowermakers present a fairly high rate of myopia (14 out of 146 examined); this class of work does not, however, figure amongst those noted as constituting an important cause of shortsightedness.

In a case studied by Vollert the use of grass plants with seeds was the cause of serious mydriasis and paresia of accommodation: it was, in fact, the effect of datura stramonium.

The authors who have dealt with this subject are Follin (1857), Vernois (1859), Van Den Broeck (1861), Charcot (1886), Pichard (Paris Thesis, 1900-1901), etc.

The legislative measures passed as regards the use of toxic colouring matters in industry (especially lead and arsenic) have effected an increasing reduction of the risk of poisoning amongst this class of worker. Never- that would have been impossible to provide special regulations relative to dipping, brushing, and drying of the colouring agents, especially when these are dissolved in liquids (methyl alcohol, carbon tetrachloride, benzol, etc.), which may liberate harmful fumes (with modern exhaust apparatus, use of tools, etc.); general hygienic precautions for the workrooms (requisite floor space, good ventilation, lighting, etc.).

Arsenical poisoning occurring amongst women workers in artificial flower factories is subject to compulsory notification in Holland. ***

Artificial Silk


Artificial silk, the chemical composition of which differs from that of natural silk (see article on that subject), is derived from cellulose and contains only a trace of nitrogen. Natural silk is distinguished from cotton and artificial silk by the solubility of its fibre.

RAW MATERIALS

The raw materials usually consist of waste cotton, and pulp of wood or paper. The last are used particularly in the viscose process.

Method. — Cellulose or its derivatives are dissolved in a suitable liquid; after this liquid has been passed through capillary tubes it is coagulated either by neutralising or diluting the solvent, or by breaking up the dissolved product; when necessary the cellulose is also regenerated.

Artificial silk is made by four methods at the present time:

(a) by dissolving nitrocellulose in a mixture of alcohol and ether, or in colloid (Chardonnet, Lehner, Tubize);

(b) by the copper ammonia process (Despeysis, Pauly — "Glanzstoff ");

(c) by the viscose process (method of Cross and Bevan);

(d) by the acetate of cellulose process.

INDUSTRIAL METHODS

Artificial Silk from Nitrocellulose

The idea of manufacturing an artificial silk is due to Réamur (1734), but the first patent only dates from 1853; that was followed by the patent of Hugues (1857) and the method of the Englishman, S. W. Swan, who passed nitrocellulose into alcohol and denitrited it by ammonium sulphide.

The first method to be used commercially, however, was that of Chardonnet (1884) based on the following processes: nitration of cotton (bleached, carded and dried); preparation of colloid by dissolving nitrocellulose
in a mixture of alcohol and ether; drawing the cellulose so dissolved into threads and evaporating the solvent during the winding and throwing processes; and, lastly, denitrating the thread so obtained.

Lehner, the factory of Tubize, and others have added several modifications to the method of Chardonnet.

Preparation of the cotton. — The cotton is bleached, carded and then dried in a drying-stove with warm air. Steps must be taken to suppress as far as possible any fine cotton dust which escapes during the carding and when the carded cotton is moved. Nevertheless fine dust is always present in these workshops, but it may be considered as relatively of little danger. In some factories nickel respirators are provided for the workers.

Nitration. — Perfectly dry cellulose (from cotton or wood) is added by degrees to a mixture of sulphuric and nitric acids. The strength of this mixture will vary according to different factors, such as the quality of the cotton and the external temperature; but, generally speaking, the mixture consists of 5 parts of sulphuric acid (at 60° Baumé) and of 2 parts of nitric acid (at 41° Baumé).

It is heated at 40° C. without pushing the nitration too far; it is dried and passed into sulphuric acid (specific gravity = 1.35); then dried again and washed with water, but not thoroughly. For the nitrated product should contain a very small quantity of free acid. The nitrocellulose so obtained is a mixture of hexanitrocellulose \((C\textsubscript{6}H\textsubscript{2}NO\textsubscript{24}O\textsubscript{5})\) and octonitrocellulose \((C\textsubscript{6}H\textsubscript{2}NO\textsubscript{32}O\textsubscript{5})\).

Dangers. — Acid fumes (especially nitrous fumes) may be set free in considerable quantities either during the mixing of the sulphuric acid with nitric acid, or during the process of nitration. Nitrous fumes (see article “Gas and Fumes”) act either in a caustic manner upon the skin and mucous membranes, or, by a general action on the system, especially on the red blood corpuscles.

Hygiene. — The health of workers employed in the preparation of the acid solution and in the nitration and drying departments bears a direct relation to the adoption of well-known hygienic measures. Some enquiries have shown that the labour turnover is decidedly high, but medical examination has not brought to light any serious troubles. It is nevertheless wise to provide the most effective means of protection, such as localised ventilation specially arranged to remove the greater part of the nitrous fumes which escape from the earthenware pots during the steeping and stirring, and especially while decanting the mixture into vats and into the hydroextractors. But it sometimes happens that in this last operation considerable quantities of nitrous fumes escape owing to the exhaust draught being insufficient.

It is often found that the material of the ventilating plant is rapidly corroded and put out of action by the acid fumes when suitable material is not employed nor appropriate technical methods applied. The hoods and ducts must be constructed of material which will not become rapidly corroded, like exposed metal, nor must they be covered with such material. The passage of dust into a chimney provided with an efficient draught has given good results.

Dissolving nitrocellulose. Drawing the threads. — Dried nitrocellulose is mixed with an oil, the drying properties of which are rendered more effective by the addition of half its weight of ordinary either. Twelve to 20 per cent. of chloride of sulphur is added while constantly stirring; it is allowed to stand and then decanted; the whole quantity is thereafter dissolved in five times the amount of methyl alcohol or alcohol and ether.

The collodion so obtained is drawn through very strong pipes, with capillary glass tubes fitted through their sides; these tubes are controlled by taps. The fluid escapes from each small opening (size from 25 to 50/100 mm.) in the form of a liquid thread which solidifies almost instantaneously, and is passed into a bath which removes the free acid as well as the solvent, and hastens the oxidation of the oil. The threads are collected by revolving drums (glass spools) upon the surface of which they are wound, or by a hollow drum on which they are deposited in hanks by centrifugal force. For dissolving nitrocellulose, acetone, acetic acid, ethyl-acetate, etc., are also used.

Dangers. — The ether-alcohol solvent (of which up to 10 or 12 litres are used for 1 kg. of commercial silk), having been used for the dilution of the nitrocellulose, evaporates during the processes of thread-drawing and silk-throwing. Danger arises in equal measure from the saturated hydrocarbons which may be found mixed with this product.
The workshops in which the thread-drawing and silk-throwing are done are, on account of the evaporation of the ether and alcohol, the parts of the factories most condemned by hygienists, despite the fact that some investigators have not found any characteristic troubles nor any particular disturbance, such as others seem to have found, even at the end of a day's work. Nevertheless, exception must be made in regard to the work of pregnant women; it would be preferable to employ them, when the pregnancy has become clear, in a workshop other than that used for thread-drawing. Similarly, in the somewhat rare case of a mother feeding her child at the breast, the same precautions should be taken.

During the throwing and waving the amount of alcohol which evaporates is very slight. Brisk ventilation is sufficient to dispel any troubles which may arise (giddiness, faintness) when beginners, who are specially liable to suffer, first enter the workshops.

Although experimental research has shown that the poisonous action of an alcohol-ether mixture is very serious and that the fumes of the mixture are more poisonous than the fumes of either alone, there is no mention in literature of any characteristic trouble among the women employed in the manipulation of threads of artificial silk.

It is especially at the commencement of their career in the workshop that beginners experience all the phases of ether intoxication: excitement, feeling of discomfort amounting almost to stupor, etc. The expired breath smells of ether or alcohol (according to the exposure). But the doctor has only on rare occasions the opportunity of seeing workers at this stage. Acclimatisation is rapidly acquired, when work can be continued without the workers showing any apparent ill-effect. Nevertheless, individual susceptibility varies considerably and it may be necessary for some workers to cease work.

The early symptoms are local troubles of the conjunctivae (smarting, watering; earliest symptoms of the effect of the fumes); and blepharitis (principally caused by contact with dirty hands). Respiratory troubles follow (cough, hoarseness, abundant nasal discharge, constriction of the larynx, dysphagia, and a desire to expectorate). If the worker does not become habituated the following symptoms are observed in the serious cases: loss of appetite, vomiting, insomnia, and periods of restlessness and somnolence.

**Hygiene (vide infra).** — For fuller details see articles “Alcohol”, “Ether”, and “Explosives”.

**Denitrating.** — The denitrating of the threads is done by means of sulphide of ammonia (with the addition of a neutral salt of magnesium) or a solution of ferrous chloride. In the latter case the threads are passed through an acid bath to remove the iron. The process then consists of rewashimg and cleansing with additions of hypochlorite of lime, washing again and drying.

If the threads are to be dyed they are softened once more with suitable reagents (soap, dilute alkalis, acids), or by solvents of the substance of the thread, such as acetone and alcohol.

**Dangers.** — These arise from the employment of sulphide of ammonia, of acetone, of alcohol, of acid fumes, of ammoniacal fumes and on certain occasions of sulphuretted hydrogen which may be given off.

During denitrating ammoniacal fumes may cause sharp irritation of the mucous membranes, especially of the conjunctivae. In order to avoid, at least in part, this inconvenience, the sulph-hydrate of soda is used instead of that of lime. The smoothing by a practised hand of the hanks (to prevent the deposit of sulphur resulting from the breaking up of the sulph-hydrate of lime) calls for the provision of indiarubber gloves for the workers, as this operation causes ulceration, or particularly painful dermatitis.

**Hygiene.** — The fumes of hydrogen sulphide and the small quantity of ammonia should be eliminated by means of localised ventilation, which must of course be installed with suitable technical adaptation and without inconveniencing the workmen employed at the vats. In the same way the very serious discomfort which is caused by fumes which are given off in the several branches of the industry — and which, according to circumstances, are strongly acid or alkaline (during the bleaching of cotton, drying, cleansing, washing, etc.) — can be kept down by modern methods, although some difficulties are occasionally encountered. Elimination of fumes is closely bound up with the removal of injurious gases.

**Silk from the Copper-Ammonia Process**

This process is based upon the solubility of cellulose in Schweitzer's fluid (an ammoniacal solution of copper oxide). The solvent is obtained by the
The precipitation of copper hydrate from a solution of copper sulphate by means of soda. The precipitate is washed and dissolved in ammonia. Another method of preparing the solvent is to make air bubble through ammonia containing metallic copper, an electric current being then passed through (Pauly).

The solution of cellulose used for threads contains 7 to 8 per cent of ammonia and a little cane sugar. The precipitation formerly obtained by 50 per cent. sulphuric acid (followed by washing the threads with acetate of ammonia diluted with a tepid solution of soap) is now obtained by an alkaline medium (with or without glycerine). The threads, having been soaked in a bath of soda lye at 48° to 50° C. (which at the same time produces a mercerisation of the silk), are then washed, passed into a bath of sulphate of magnesium or aluminium (in order to displace the base) and again washed and dried. The thread after twisting is wound on bobbins. The copper remaining in the thread is removed by passing it through dilute acid. This is followed by washing, cleansing with soap, and drying.

Dangers. — In the copper-ammonia process risks arise from the employment of alkalis and acids.

Some workmen in Germany in 1919, who were employed in washing artificial silk with lye, suffered from very painful dermatitis, confined to the hands and forearms. In another German factory irritation of the eyes and of the skin due to the ammonia were noted, but such cases were completely abolished by introducing a good system of localised ventilation. The fumes absorbed were washed with dilute sulphuric acid in order to eliminate the ammonia.

The Viscose Process

This process, dating from 1892, is the one which is most widely applied. In it use is made of waste cotton and especially of paper pulp. A remarkable product is obtained, namely the thio-carbonate of cellulose, or "viscoïd". Viscose is a viscous solution of xanthate of cellulose and of sodium, obtained by the action of sulphide of carbon upon alkali-cellulose. Paper pulp in leaves bleached by bisulphite is placed in a special chamber at a temperature of about 20° C. in order to maintain for the paper a constant percentage of humidity (from 10 to 12 per cent.).

The steeping and pressing of the paper takes place in vats (steeping presses) into which is directed soda, or the steeping lye (at 20 per cent.), which is a solution of the soda used in commerce (or of caustic soda), in water, mixed with the soda used in the pressing. A male screw movable in a female screw and holding a large metal plate ensures slow compression of the leaves of paper in the mixing vat itself. The excess of alkali is removed at the lower part of the vat.

The leaves are then spread out on canvas sheets and dried for 15 minutes.

The alkali-cellulose so obtained is an oily pulp of a white or yellowish colour, slightly transparent or silky in appearance. This pulp is then ground between granite millstones (or better in crushers or mills) and allowed to stand for from 48 to 72 hours at a fixed temperature. The ground or crushed alkali-cellulose, which, after it has lost a light flaky product is then treated with bisulphide of carbon in a hermetically-sealed mixer with temperature regulated by water circulating through a water jacket. The process is stopped when the mass assumes an orange colour and is slightly sticky to the touch. The excess of bisulphide of carbon is evaporated at the end of the reaction by a system of vacuum tubes.

The pulpy mass is then dissolved in a solution of soda by means of "mixers" and a homogeneous solution obtained, which is the brown or black, and very viscous, colloidal salt of viscose; it is filtered and then allowed to stand for some days (the maturing process). The soda contained in the mass is then neutralised by the addition of ammonium sulphate; it is next filtered and the filtered solution is thereafter subjected to the action of a vacuum.

Hydrocellulose, made according to the method of Girard, may be substituted for pure cellulose; in that case the consumption of soda and sulphide of carbon is much reduced.

Thread-drawing is done as for the other silks. The thread coming from the capillary tubes is coagulated by means of a cold bath of ammoniacal salt followed by boiling. It is then washed and treated with lye-wash, hypochlorite of soda and dilute acid; after which follows desiccation and drying. Other makers produce coagulation by means of other agents such as bisulphite of soda, ferrous sulphate, etc.

The product obtained can be bleached or rendered impermeable by means of formaldehyde in the presence of acid, etc.
Dangers. — These arise mostly from the sulphocarbonic fumes. Lehmann mentions serious troubles which occurred among women workers at a Hungarian factory in 1909: headache, gastric trouble, diminution of sight, psychic condition, delirium, and even loss of consciousness. Some similar cases have also been reported recently (1924). The poisonous action of the vapour of carbon bisulphide is favoured by the temperature, so that during the warm season cases of sickness and poisoning are more frequent. Dermatitis, caused by the irritating materials, has also been reported. Inflammable products utilised may give rise to fire and explosion.

The thread-drawing operations are usually carried out at a temperature of 18° C. with a humidity percentage of about 60. This percentage is sometimes exceeded, especially in the processes of washing, winding on reels, and retwisting (up to 70 per cent. relative humidity). In Italy also it has been remarked that workers who come from the country only become acclimatised with difficulty and that managers have to hold a reserve personnel (6 per cent. for men and 12 per cent. for women in 1924).

According to a recent report of the French inspectorate (Chevalier, 1922) no serious accidents or cases of poisoning, even of a slight degree, have occurred in a factory using the viscose process.

The sulphide causes very little harm when a tightly closed apparatus is used with exhaust ventilation for fume removal. In the same way sulphuretted fumes (sulphuretted hydrogen, etc.) should be removed by good localised ventilation. After bubbling through a vat containing caustic soda, the fumes should be discharged into the atmosphere from a very high chimney.

The fairly serious troubles, reported since 1910 by the German factory inspectors as caused by bisulphide of carbon, have in the course of time been largely reduced by the introduction of more effective apparatus.

In the Dutch viscose factories dermatitis (confined to the fingers) has been noticed among the workers in the bleaching section, and cough caused by the action of the fumes of chlorine and hydrochloric acid. The attention of medical practitioners and of the medical inspectors of labour has been drawn to quite a large number of cases of an affection of the conjunctival epithelium, a superficial keratitis (Nederl. Tijdschr. v. Geneesk., 11 August 1923, page 576). Dr. Bakker, who has studied these cases, says that the keratitis has a close resemblance to electric keratitis. He has excluded sulphuretted hydrogen as a cause and attributes the condition to some organic compounds of arsenic or other similar compounds. He has drawn attention to the facts that good ventilation has sufficed to prevent the troubles which were formerly of such frequent occurrence among the workers, that such workers show no other symptoms of poisoning by sulphuretted hydrogen, and that this gas was detected at the level of the head of the workers in a strength not exceeding 0.09 mmgr. per litre. He is of the opinion that the organic compounds of arsenic are able to exert their poisonous action in a strength of a hundred millionth of a milligram per litre of air, and that in the viscose factories in which solutions containing chlorine are employed arsenic is always present as an impurity. These solutions acting upon organic compounds (cellulose) may, then, set free in the course of complicated reactions products similar to those in question.

Lehmann, having directed his attention to this subject, has put forward the opinion that sulphuretted hydrogen is likely to be the cause of the troubles rather than organic compounds of arsenic. Similar cases reported in Germany, France and Italy have as a matter of fact been attributed to the action of sulphuretted hydrogen. In Italy it has been shown that small drops of alkaline solutions of sulphate and bisulphate of soda or of xanthogenate carried to the eyes by dirty hands have also caused conjunctival troubles. Clearly, if certain operations are done in a manner which is a little primitive (especially the filling of the baths, the taking of samples) more acid fumes will be emitted in consequence and the particular troubles will be both more serious and more frequent.

In addition, Parmenter described in 1921 some cases of poisoning by tetra-chloroethylene which had been previously reported in an American factory among workers employed in winding the thread on bobbins and drying it. The number of cases among 95 persons during five months was 21, of which 9 were fairly severe.

The Acetate of Cellulose Process

This process, which is quite recent, makes use of the triacetic acid compound, or triacetate of cellulose, with various acetic ethers of cellulose. Bleached and dried waste cotton is treated with a mixture of acid and
acetic anhydride for several hours at a low temperature in the presence of a catalyser (sulphuric acid or the sulphate or chloride of zinc, etc.). It is then diluted with 50 per cent. acetic acid with sulphuric acid added to it; it hydrolys for three hours and is allowed to mature. The acetate of cellulose is precipitated by cold alkaline water if the solvent mixes with water, if not by alcohol, or benzene; it is then filtered, washed and dried. The white flaky mass so obtained is scarcely inflammable at all; it is insoluble in water, in methyl alcohol, ethyl alcohol, benzene and carbon tetrachlorid. In order to draw the thread use is made of its property of dissolving in acetone, glacial acetic acid, formic acid, chloroform, methyl acetate, acetalddehyde, tetrachloroethane, etc.

The thread produced coagulates very rapidly and, after washing and drying, is ready for use. The silk obtained can be considered as a pure ether of cellulose.

Dangers. — These arise in the course of the preparation of nitrocellulose and thread-drawing, from the employment of alcohol, ether, glacial acetic acid, benzene, tetrachloride, carbon, tetrachloroethane, acetone, etc., containing up to 30 per cent. of sulphurous anhydride, etc., used in the various processes of the manufacture of artificial silk.

Uses

The uses of collodion, of viscose, and of acetate of cellulose are very numerous. In addition to the making of different artificial silks, they are used in the preparation of varnishes and lacquers (see also article "Tetrachloroethane"); for waterproofing fabrics; for gumming paper used for packing; for embedding paper or materials when receiving art impressions; for preparing materials (in dyeing); as a mordant in treating cotton with iron, aluminium or chromium; for the manufacture of films (cinema and photographic), and of insulating material (used in electrical work); for capsules for bottles; for sponges; for bristles; as a substitute for gelatine (mixtures of viscose with viscose, and collodion, mixed with india-rubber and celluloid); for billiard balls; and generally as a substitute for wood in the manufacture of small articles. The solution of cellulose nitrate in alcohol ether (collodion) is well known and is used in photography; in surgery, in the manufacture of artificial silks, in that of celluloid and of cellulose ether see those articles.

Hygiene

The special precautions recommended for the construction of factories classed as dangerous or unhealthy on account of danger from fire or explosion must be taken.

Operations should be carried on in closed apparatus or provided with ventilating hoods connected with an efficient system of ventilation. Removal of poisonous fumes (nitrous, alcoholic, ether, bisulphide of carbon, etc.) should be carried out in connection with a recovery process by ventilation as far as possible localised or in closed apparatus. Wherever it is possible manual labour should be replaced by machines. Greasing of the hands or wearing india-rubber gloves may be recommended in order to avoid contact with irritating substances, but the workpeople consider these measures of no value and generally do not adopt them. In one German factory women, found too susceptible to dermatitis, were replaced by men.

It is not possible to state in detail here the best measures for preventing the escape of fumes. It is a difficult problem which requires a particular solution for each factory. It is in fact the problem occupying the attention of all industries in which fumes escape (see articles "Air: Hot and Humid", "Textile Industries", etc.).

The condensation of poisonous vapours, and especially those containing alcohol ether, is an operation important from the viewpoints both of economy and health. The recovery of these products represents considerable progress in hygiene, although very serious technical difficulties are encountered. The collection of the fumes should be effected at their point of origin without allowing them first to diffuse in the air of the workshop.

Residuary fluids should be subjected to chemical treatment by lime, salts of iron, etc., precipitation of solid materials, aeration, etc., before they leave the factory. Acid fluid from the nitration and alkaline fluid from the washings to remove the sulphides, neutralise each other; but the denitrification of the waste water is never complete, and it always contains nitrates, sulphides, or at least sulphur.

If escape of sulphuretted hydrogen is feared it is desirable that the air should be analysed at regular intervals (this method was adopted in a German factory).

It is equally desirable that the workers should be examined every three months and that those who are not in
good health, or who show a predisposition to the kinds of sickness described above, should be removed. If possible a rotation of workers should be organised. Persons exposed to risks at their work should be instructed as to these, and facilities for personal hygiene should be placed at their disposal.

The risk of fire from solvents is much more serious than that from nitrocellulose. In fact it has been found that nitrocellulose with above 30 per cent. of water is not inflammable and that the solution in alcohol ether can be quite well used, even with a hydrate of cellulose at 40 per cent. As precaution against outbreaks of fire, there should be a good system of hydrants lodged in the most convenient places, and of hose-pipes arranged near the roof of the workroom and capable of being easily manipulated by the workers themselves. An automatic system for flooding those parts of the workshops when the temperature for any reason reaches 50° C. should be required. With regard to thread drawing, the product burns slowly and a woman worker always has time to extinguish any fire at its commencement with a pail of water placed at the end of each machine.

LEGISLATION

No special regulations exist for the manufacture of artificial silk. As regards the protection of women and children, and the compensation of industrial diseases, see articles " Alcohol", " Ether", " Carbon Disulphide ", " Explosives ", " Celluloid ", " Nitrocellulose ".

Notification of cases of conjunctivity is compulsory in Holland.

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Artists


Under this title are included data on occupational pathology relating to artists, understanding by this term all persons carrying on an artistic profession connected with the theatre — dramatic and lyrical, dancing, music, painting, sculpture, etc. Cinema artists, lecturers, acrobats, etc., are also included.

Stress, however, must be laid on the fact that the data are few and scattered throughout medical literature. Only of late years (1925-1926) have new studies commenced to appear. These relate to special categories, for instance musicians, and it is to be hoped that the specialists will direct their attention to the different branches of this art in order to make a more intensive study of its pathology.

It is impossible to analyse even briefly the very detailed enquiry of Peri (1913) on the professional pathology of dramatic artists and the hygiene of the theatre.

This enquiry confirmed the findings of Brown, carried on mainly among French artists, showing that damage to health is bound up with their profession and the surroundings in which they pursue their calling. If attempts were made to summarise the different ill-effects revealed by Peri, they would be found to be:

(a) Causes exclusively personal to the "child of art": weakly constitution; nervous temperament; predisposition to tuberculosis, syphilitic heredity, etc.

(b) Causes connected with the profession: excessive exertion of the respiratory system and especially of the voice in recitation; the strain on attention; nervous tension while on the stage; hard work.

(c) Causes connected with life in the profession: irregular meals and rest, etc.; frequent changes of climate and food; moral effects; poor pay; preoccupation for the future and for the family; feeling of discouragement following on excessive criticism by art directors, etc.

(d) Causes resulting from the vices easily contracted by artists: abuse of alcoholic drink and tobacco; sexual excess; addiction to drugs, cocaine, morphia, etc.
Professional diseases are very frequent among dramatic artists; anaemia, chlorosis, chills, illness due to dusts, tuberculosis, alcoholism, digestive and circulatory troubles (varicose veins), etc. Fatigue of the voice troubles, etc., also are frequent.

Among forms of chronic poisoning, that from lead should be mentioned, arising from paints (make-up) with a white lead basis. The same thing is reported at present among the artists of eastern counties.

Brown recalls also the fact that artists, often compelled to live in dirty lodgings, run the risk of contracting infectious or parasitic diseases (itch, pediculosis and syphilis, etc.). He mentions, too, the danger to be anticipated from the loan of clothes, wigs, etc.

A peculiar timbre, and a peculiar timbre of the voice is known (that of a famous actress).

Recently (1925) Schlafranova, again emphasising the scantiness of contributions to medical literature relative to artists, has drawn attention to the profound influence on the emotional side of any form of professional fatigue of long standing. Among the professional neuroses of actors that results from the fatigue of the preparatory work of interpreting a role, the symptoms and the physical fatigue sometimes involved in the part; hence the physical and mental exhaustion acting generally of inherited neurotic temperament.

Pulmonary emphysema is the most frequent lesion among persons whose work necessitates continual deep inspiratory and energetic expiratory efforts.

Myocardial hypertrophy as the results of the preparatory work of interpreting a part (study of the rôle, examining documents to understand it properly, etc.), and the physical fatigue sometimes involved in the part; hence the physical and mental exhaustion acting generally of inherited neurotic temperament.

Among dancers, besides the physical fatigue and consequences of the considerable effort demanded of the circulator and respiratory system, there are the ocular effects produced, mainly by the action of the luminous rays (white and coloured) thrown on the stage and often on the artist himself. Several cases of eyestrain, retinitis, etc., have been described. The tiring effects of the serpentine dance on the eyes of the dancer who evolved and carried it out in very brilliant coloured light are known.

According to a report in the Deutsche Musiker Zeitung (1925), professional diseases of musicians have not received the attention they deserve. It is, however, notorious how artists who play on stringed instruments (violonists, harpists, etc.) raise callosities on the fingers, which may become inflamed and suppurate. They suffer also very often from pain localised in the fingers of the left hand which may cause incapacity of long duration. The part of the hand attacked swells and exhibits circulatory changes. Diagnosis is difficult, a fact of importance if compensation is in question. The pain is localised, mainly in the thumb and index finger. The latter shows a small red patch of small size, which from which the coagulum can be easily removed. The skin around the nail is affected more or less widely; the pain is situated in the palm, on the right thumb, and even in the wrist and forearm. This pain is very common as a result of overstrain among pianists, in whom the pain extends to the shoulder, especially after playing pianissimo for a long time. A fairly frequent cause of the trouble is to be...
found in a faulty manner of holding the instrument or in the faulty position adopted in playing.

The maladies most commonly found are functional nervous affections, especially among pupils obliged to gain their livelihood, and who should be induced to avoid abuse of excitants such as coffee and tea.

Myopia is peculiarly prevalent among artists and particularly amongst a certain class. Thus, for example, a person playing a stringed instrument must have his music stand at a distance of over half a metre. This distance, however, should have little effect on refraction. Other players bring the stand nearer, especially if the music is written in small characters or in a cramped style. Myopia often is found among composers and conductors engaged in theoretical study, but it affects principally the music copiers.

Stillings is of opinion that the number of musicians affected by myopia is very large, and believes it to be caused by their having to look downwards so much. Cohn does not share this opinion, as he classified the ocular defects in musicians and, of 60 per cent. of those examined, found only 32 per cent. troubled with myopia. His opinion was that the myopia had existed before the persons in question took to music; nevertheless, it should be noted these people had been copying music for a long time and principally at night time; 9.7 per cent. only had become myopic during the time they had been engaged in the work.

A study of the stigmata of a violinist's hands and fingers necessary, the character of the movements and the condition under which they are made (exercises for studying the piece, for concerts, etc.). The absorption of oxygen is also increased, as well as elimination of carbon dioxide and the heart's activity. In healthy and well-trained persons the heart resumes its normal rhythm soon after the close of the piece.

Finally, Chlopine states that the work of the pianist must be ranked among those requiring the highest qualifications as it demands the expenditure of so much physical and psychical force. A neurosis characterised by pain and cramp and a sensation of fatigue and constriction localised in the right knee has been reported in players on the triangle and drums which are set in motion by a pedal (Aldrich). Each blow, it was calculated, required an effort of 5 to 12 kg. and the artist had to give 180 blows a minute. Von Strumpell assembled 62 cases of paralysis among drummers affecting the extension of the distal phalanx of the left thumb. Chronic tenosynovitis is said to be a fairly frequent consequence of the way in which the drum sticks are held, setting up mechanical irritation of the tendon of the long extensor of the thumb and, more rarely, even rupture of the tendon at the moment of the paroxysm of rolling, and, still more rarely, even spontaneous rupture.

Among the professional neuroses, first and foremost is the cramp of the pianists, especially common among young women, but which has been reported in men over forty.

Violinists' cramp of the right hand rather than the left is interesting. Cramp may often affect such musicians as players of the organ, the harp, the flute, and even conductors; in the last named it takes the form of a neuralgia localised in the muscles of the right shoulder (Curschmann).

Cramp of the legs is less frequent, but can occur in dancers who rest too long on the point of the toes. Cases of neurosis affecting co-ordination of the head are fairly rare, but some have been described, e.g. as affecting a flute player (Von Strumpell) who developed a cramp of the tongue, and a trombone player and trumpeter (cramp of the muscles of the mouth).

A study of the stigmata of a violinist's profession by Calobresi raises them to the number of five: stigmata localised in the neck showing the cutaneous reaction, either circular or irregularly elliptical and generally occupying the parotid or subhyoidean region on the left side and due to the injury caused by the violin: callosities on the fingers of the right hand set up by holding the bow. Chronic tenosynovitis is said to be a fairly frequent consequence of the way in which the drum sticks are held, setting up mechanical irritation of the tendon of the long extensor of the thumb and, more rarely, even rupture of the tendon at the moment of the paroxysm of rolling, and, still more rarely, even spontaneous rupture.

In players on wind instruments lesions of the teeth are frequently observed (especially of the incisors), as well as spasm of the tongue and muscles of the larynx. Emphysema, formerly so frequent in military musicians, has not been found either by Fischer (who examined 300 players) nor by...
physicians. However, an enquiry by Kahn, Herzheiner, and Brose (1925) among 50 athletes over 40 years of age did not show that they suffered from circulatory diseases or arteriosclerosis. On the other hand, some of these athletes were found to suffer from a slight degree of aortic dilatation, for which the authors were unable to furnish a satisfactory explanation.

Some writers maintain that cases of nervous diseases are common in artists generally and most frequent in painters. The nyctagmus believed to have been contracted by Michael Angelo from painting the frescoes in the Sistine Chapel is a classic instance, and has been attributed to forced retraction of the head. The instances of lead poisoning, so common in the Middle Ages among painters, seeing that they ground the paint colours themselves, have disappeared nowadays, although cases are occasionally reported among artists on retouching work who prepare sketches for posters. Fifteen cases were reported to the Illinois Committee of Enquiry among members of the Painters’ Society who had contracted the poisoning by permanently poisoning the paint colours with lead. They thought they were dealing with zinc paints, but they were really white lead.

Sculptors are sometimes attacked by paresis or paralysis of the hands. The action of some kinds of dusts might also play a part in the etiology of certain respiratory troubles and irritation of mucous membrane of the nose and eyes.

The first case of paralysis among sculptors was perhaps that described by Sand, of Brussels, in 1910 as affecting one of the greatest Belgian artists. Naturally, an attack of weakness and enfeebled by years of hardship and dis-appointments, originally a painter, for the last twenty years he had been engaged in sculpture for ten hours a day. Atrophy involved all the muscles of the right hand supplied by three different nerves. The condition had come on in subacute form following severe influenza, which had fatigued the muscles of the hand. He recovered completely, although slowly.

Sand remarks that the sculptor uses not only the thumb and index finger, but that the preliminary work, the "massage", consisting in kneading and compressing masses of clay and in particular the other hand, some of these athletes were found to suffer from a slight degree of aortic dilatation, for which the authors were unable to furnish a satisfactory explanation.

The extraordinary development of the cinematographic industry has brought with it a whole series of injurious effects on the persons engaged in it. This has occurred naturally to the great army of artists and players working out the scenarios, among whom numerous prejudicial effects have been noted not only on the general health but also on certain organs in particular. In addition to fatigue and a peculiar neurosis known as "cinematographic fatigue or neurosis" attention has been called to very serious lesions of the eyes. Already quite a literature on the subject exists, as well as on the problem of the lighting of studios.

These lesions, which are set up by the electric lighting, comprise generally cases of kerato-conjunctivitis, the majority of moderate severity, but healing readily. The cornea also has been involved, especially when the patient has been myopic. According to Sedan (1925) while lateral illumination plays a very important part in producing the lesion, the factor duration of exposure, on the other hand, to the rays is practically negligible. An individual tolerance may be produced, but is not present among those taking up the work for the first time. Electricians, managers, and mechanics are less affected by these eye injuries, either because they adopt the necessary precautions, or because they have become acclimatised to the luminous rays.

Mercury vapour lamps seem to be innocuous. But measures of prevention to which reference is made later meet with practical difficulties raised by the necessity for "make-up" of the artists.

The lesions arising from the powerful sources of electric light affect the skin and the eyes. The skin lesions are characterised by swelling of the skin, especially of the eyelids, and very severe pricking sensations. They terminate in desquamation, leaving a brownish pigmentation more or less persistent.
The conjunctiva is injected; the patient feels as if sand were in the eyes and the lachrymal secretion is increased; the eyelids, on waking, stick together; the patient complains of photophobia, fatigue, weeping and weak sight. The question of lighting of studios was also discussed in 1920 by the Illuminating Engineering Society. The opinion was expressed that, from an artistic point of view, use of diffused light approaching more nearly that of daylight was most desirable. Seeing that lighting is one of the least costly items in the production of a film, obviously a little more money should be applied in this direction so as to obtain more healthy lighting and at the same time more satisfactory conditions from the point of view of technique.

Directors of studios ought to pay attention to the quantity of rays emitted by the different sources ordinarily used, because the colour and the richness in ultra-violet rays vary considerably for certain types of lamps.

In England a committee composed of representatives of the cinematographic industry, ophthalmic surgeons, photographers, and others was formed in 1921 to study the whole subject of the illumination of studios in all its aspects.

While the ultra-violet rays are the most injurious, they are not the only ones; because violet and even blue rays can produce the detrimental effects.

Since the very refractive rays cannot be kept back by yellow glasses in front of the eyes of the artists, then yellow screens ought to be placed in front of the arc lamps. Unfortunately, the ordinary film is not sensitive to light transmitted through the yellow screens, and as this cannot be overcome either by longer exposure or increasing the light, some other type of panchromatic emulsion for the film must be sought which, like the retina, is sensitive to colours of low refraction.

If some such result could be achieved notable progress would be possible for the industry (Comandon).

The heat given off by the sources of light must not be forgotten, as they cause the atmosphere of the studio to be heavy, especially in the summer. The artists complain of physical depression analogous to that experienced in summer before a thunderstorm. Fresh air alone can remedy that.

Technicians who have to keep an eye on and regulate the lamps may also be affected by the injurious action of the sources of light used in the studios. The glass of these lamps, therefore, should be fairly opaque so as to keep back any dangerous quantity of ultra-violet rays.

**Legislation**

A Bill in Czechoslovakia (1925) proposes provisions of old-age pensions for artists, writers, and composers so far as they are not already insured elsewhere and are without means.

In France there is no special regulation as the labour laws are applicable to such work. A Bill was, however, presented to the French Senate in January 1926 proposing a modification of the Industrial Code so that children under 15 years of age (instead of 13) should not be employed on the stage as actors or in theatres, café concerts and other establishments, including cinemas.

In Germany the Act of 1903 on the employment of children in industrial undertakings has been amended so as to apply equally to their employment in studios (31 July 1925); their employment, subject to certain exceptions, is prohibited in the production of films. Except in the interests of art or science, no authorisation is allowed to children under three years of age; for those above this age the authorities must satisfy themselves that the work is not such as to affect physique or morals. An Order on the employment of children in the taking of films has been issued by the City of Berlin (30 June 1924). According to the Deutsche Musikzeitung German musicians are demanding a regular contract with the right of a pension for old age and compensation for dependants in case of death (1925).

The same is the case in Great Britain which has no law expressly dealing with employment of children in cinematographic studios. The Home Office understands that such employment is very rare. Even if the Factory and Workshop Act, 1901, and the Employment of Women and Young Persons in Theatres, etc., Act are inapplicable, the Education Act, with its clauses regulating generally the employment of children, still applies and can be enforced. Practically all local authorities have now made by-laws for employment of children in studios, but no intervention of any local authority has so far occurred.

A pension scheme is provided in Greece by an Act of 20 October 1925 for artists employed in theatres.

In Italy the recent Act of 10 December 1925 on the protection of children prohibits the employment of children under 15 years of age on the stage, where they are engaged as actors, walkers on, etc., in cinema performances or in open-air entertainments, and those under 16 years of age in dangerous acrobatic feats.

In the Netherlands musicians' cramp is compulsorily notifiable.

In the United States, the State of New York has laid it down that children under 16 years of age may not take part in film production without the authorisation of
extensive. Including lessons lasting four hours given in part in film production must not be made every three months. Carried out by a medical man in the Child can be employed in a studio unless duly no child under at least 16 years of age week.

Asbestos is most commonly used; the first of these is the hornblende asbestos which are the most serpentine known by the name of talcator and is not attacked by most acids.

When cut up it presents a silkycotton-like form which lends itself easily to weaving. It is incombustible, prevents heat loss, is a thermic and electric insulator and is not attacked by most acids.

The uses to which asbestos is put are very varied. The long fibres are used in the textile industry for the manufacture of cloth, braid, rope, theatre curtains, decoration, upholstery, hangings, and for finishing pistons for steam engines. The shorter fibres together with an agglomerating agent are used in the manufacture of felt, paper, cardboard, varnishes, covering agents (especially for strong

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**Asbestos**


**Chemical Properties**

Asbestos is a brilliant filamentous mineral, oily to the touch, white, silvery grey, greenish or bluish. Its density is 2.3-2.9. Its chemical composition consists, according to its origin, of calcium silicate and magnesia or of a magnesia silicate accompanied by quantities of iron, more or less extensive. Analysis of different varieties of asbestos reveals a silica content of 40-50 per cent. — 41.2 in Canadian asbestos, 41.8 in Siberian asbestos, and 51.1 in the African variety — while oxide of magnesia varies between 2.3 (African) and 41.7 (Canadian), oxides of iron between 2.52 (Canadian) and 35.8 (African). In Siberian asbestos there is besides 16.39 per cent. of alumina. When cut up it presents a silky cotton-like form which lends itself easily to weaving. It is incombustible, prevents heat loss, is a thermic and electric insulator and is not attacked by most acids.

Of the three different mineral varieties known by the name of asbestos, it is serpentine asbestos or chrysotile and hornblende asbestos which are the most commonly used; the first of these is the most sought after variety. Industrial asbestos is chiefly derived from Canada, Russia, Italy, and the Transvaal.

**Technology**

Extraction involves two distinct operations: (1) quarrying of the asbestos-bearing rock, generally mined in open quarries or, in countries having a severe winter climate, in galleries; (2) separation of the asbestos from the surrounding rock. The rock is cut in terraces, sometimes reaching a depth of some 150-200 ft. Quarrying is more economical and effective than underground work even despite exposure to weather. Drilling and blasting are engaged in as in ordinary stone quarrying. The mineral got from the quarry is rough sorted, different grades being chosen for length of fibre and sent to "cobbing sheds" where dressing is carried out. This consists of separating the asbestos fibres from the surrounding rock and may be done (a) by hand — the stone being broken by a small sledge hammer and the fibre thrown thereafter into one box and the waste into another — or (b) by machine ("mills").

Hand separation ("picking and sorting") is not difficult since the fibres lie in layers more or less loosely attached to the rock and can frequently be picked off with the fingers; hand dressing is not thorough and the waste material from the cobbing tables contains much fibre, the further utilisation of which represents large profits to the mine, and these fine pickings have to be dressed mechanically. They are passed after drying to crushers where they are broken by successively finer-set rollers and further reduced by cylindrical fibreisers and the cyclone machine, which reduces them to fine powder. The cotton-like fibres come to the surface and are mechanically withdrawn by suction. The pulverised rock and ground asbestos are then separated by passing them through a shaking screen. In some mills the particles of iron present are taken up by strong electric magnets. The crude fibre on separation from the waste rock resembles mineralised wool. The asbestos is graded according to the length of fibre on a series of cylindrical screens. It is then carded and packed in sacks and placed on the market in bulk.

**Industrial Uses**

The uses to which asbestos is put are very varied. The long fibres are used in the textile industry for the manufacture of cloth, braid, rope, theatre curtains, decoration, upholstery, hangings, and for finishing pistons for steam engines. The shorter fibres together with an agglomerating agent are used in the manufacture of felt, paper, cardboard, varnishes, covering agents (especially for strong...
rooms), cements, rubber tyres for automobiles and bicycles. Asbestos is also used as an electrical insulator for covering electric wiring for high and low pressure currents, in the manufacture of tiles, planks, panelling and exterior coverings for buildings, mattresses, heat insulating gloves, firemen's clothes, laboratory equipment, porcelain, balls for gas fires (made of fireclay and asbestos), etc.

**Dangers and hygiene**

The worker engaged on the extraction and manufacture of asbestos is constantly exposed to danger from dust, more especially, however, in the operations of spinning and weaving.

The baneful influence of the dust in relation to the production of tuberculosis is brought out in the Annual Report of the Chief Inspector of Factories for England and Wales for 1910, which records 5 deaths from tuberculosis amongst 40 workers engaged in an asbestos weaving factory, where the most dangerous process was revealed to be the weaving of asbestos mattresses composed of bags of woven asbestos filled with short asbestos fibre. They were placed on a table and beaten out flat by a man with a wooden flail, which process occasioned the production of much dust. Women sewed the mattresses into sections using asbestos threads and as they worked beside the beaters they also of necessity inhaled much dust.

Towards the beginning of 1924 a fatal case of poisoning by asbestos dust was reported at Rochdale (England). The victim was a woman who had been employed in an asbestos factory. A post-mortem examination revealed death as due chiefly to a fibrosis of the lungs due to the inhalation of mineral particles and in part to tuberculosis. A microscopic examination of the lungs and of dust samples taken from three different workshops of the factory revealed the same black particles present in each, alike in form and dimensions.

Another fatal case was studied in 1927 by Cooke and Hill (Great Britain). A striking example of the noxious property of asbestos dust is instanced by the following case: in an asbestos spinning and weaving factory (Calvados) there were 40 deaths in the five years 1890-1895. The mortality rate decreased considerably with the installation of a good system of local ventilation over the carding machines.

(See also article "Tuberculosis.") In an asbestos weaving factory in Saxony the workers complained of headaches and loss of appetite. These affections were caused by fumes given off by a rubber solution with which the asbestos cloth had been coated to eliminate dust.

An investigation carried out in Canada in 1911 revealed that hygienic conditions were greatly improved as a result of the adoption of an effective system of ventilation. Nevertheless, a local doctor with long experience stated that respiratory troubles, and in particular tuberculosis, were of very frequent occurrence amongst asbestos workers.

Rambousek drew attention to the risk of lead poisoning during the weaving of asbestos when a thread of lead is added to the weft, as is sometimes the case.

Marked frequency of chronic conjunctivitis, with hypertrophy of the rims of the pupils has also been noted amongst the asbestos workers of the Island of Cyprus. The workers in question were chiefly engaged in grinding, screening, and packing the asbestos in sacks.

The weaving of asbestos has only developed importance during the last twenty years. Now that it is widely practised the application of local exhaust systems during such processes as that above described is called for. All processes from extraction onwards unquestionably involve a considerable hazard, and American and Canadian life insurance companies generally refuse asbestos workers on account of the assumed deleterious conditions in the industry.

The lack of more accurate and detailed data in medical literature regarding this industry in its various branches, including the utilisation of by-products, is to be deplored in view of the self-evident importance of asbestos dust as a predisposing cause of pulmonary tuberculosis, more especially since the rapidly-increasing development of industries utilising asbestos adds greatly to the urgency of studying the conditions with a view to their amelioration.

All provisions already described for withdrawal of dust should be enforced in this industry.

**Legislation**

In Italy boys under 15 and girls under 21 years of age are excluded from workshops where dyeing and weaving of asbestos are engaged in, unless effective
means are taken to prevent the diffusion of dust throughout the atmosphere.

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**Ashes, Cinders**


Ashes present problems from the point of view of industrial hygiene, not only when cinders from hearths are in question (dangers from hot dust, presence of certain products, etc.), but especially when they are employed for special purposes. Thus, for instance, treatment of goldsmiths’ ash by lead may cause injury by reason of the metallic dust which it liberates.

Hygienic measures assure covering of any openings giving on to the public streets, thorough ventilation of the workshop, the installation of hoods for the furnaces and cupels connected to the chimney by a strong exhaust. If the treatment is effected by means of mineral acids, application of measures of protection against toxic fumes is required, viz., condensation of lead fumes. Noisy machinery should be isolated, and measures applied for evacuation of residues and the protection of workers from the heat and glare of the furnaces.

Pearl ash from combustion of organic material, such as shoots of vine, wine lees, vinasse from beetroot, etc., is composed of impure potassium carbonate and its treatment liberates sharp, piquant, thick, and disagreeable fumes and injures vegetation in the neighbourhood. Factories should be erected at a long distance from dwelling houses and calculation should be effected in closed ovens. Gases and fumes should be led to special hearths or requisite measures taken for their destruction. The chimney must be a very high one. It would be advisable to collect the incandescent mass of carbonate of potassium in a special apparatus so that the gases of combustion may be burnt. Hoods should be installed above the evaporation boilers. The water should be fed to a sewer; the residues require fairly frequently to be removed and can be utilised as manure.

By the expression “dust shot with a lead content” is meant the impure oxides which form in the vats where each bath containing lead or lead alloys. This scum or black dross is removed as it forms and is often put aside on the floor, where it becomes mixed with other substances. In appearance it resembles ashes, hence the French expression “cendres de plomb.” Kelp ash is lixiviated for the extraction of the salts of potassium. The ash is got by burning different kinds of sea-weed known as kelp or wrack and thrown up on the seashore. Dried in the sun, they are thereafter reduced to ashes in furnaces lined with refractory bricks. The product of this process of reduction, or “kelp ash” is in the form of a solid compact block, from which the salts of potassium are extracted. The blocks are then ground and put into special apparatus for gradual dilution with water. The solution is concentrated in iron boilers and poured into vats where, after cooling, the potassium chloride is deposited in crystals, which are then subjected to purification.

Hygienic precautions to be recommended are impermeable flooring, cement walls to the height of one metre, hoods provided above the boilers to draw off the fumes to the chimney, all openings to the public highways to be kept closed, and neutralisation of the water used before it enters the sewers.

The Recommendation adopted at the International Labour Conference at Washington (1919) regarding the protection of women and children against lead poisoning demands the exclusion of women and young persons under eighteen years of age from work involving manipulation, treatment, and reduction of ashes containing lead.

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**Asphalt**

(Mineral Pitch, Hard Bitumen)


Earth and rocks impregnated with bitumen are called asphalt. In mineralogy, however, the name asphalt is also given to bitumen in a free state. It is highly important to distinguish between these two products. Asphalt is generally in the form of fine grained rock, black or dark brown in colour according as it is more or less
rich in bitumen. The earth or rocks impregnated are in general calcareous rocks, dolomites or sandstone.

Bitumen is the solid product deriving from slow decomposition of organic matter. It is composed of a mixture of heavy hydrocarbons containing, besides oxygen, nitrogen and sulphur compounds. In commerce it is frequently met with under the name of asphalt.

Whilst the best known deposits of asphalt are found in Switzerland, France, Italy, and Dalmatia, the deposits richest in bitumen are those of the Dead Sea, Trinidad, Cuba, Bermudas, Venezuela, the United States, Mexico, Russia, etc. The extremely large deposit in the Lake of Trinidad fills the crater of an extinct volcano, and it is estimated that it contains 158,400 tons of asphalt per foot of depth and in the substratum of this deposit large quantities of petroleum are found. It is supposed to be produced as the result of evaporation and oxidation of liquid petroleum which has escaped from the outcropping strata.

Asphalt is a solid or semi-solid mass black or blackish brown combustible burning with a fuliginous flame. Its specific gravity varies between 1 and 1.6. It is insoluble in water, soluble in ether, petrol, carbon disulphide, etc. It is often replaced in commerce by pitch, the residue of coal tar distillation.

Refined bitumen coming from the Isle of Trinity is purified by fusion at about 160-170° C. It becomes soft at 85-95° C, and contains 55-65 per cent. of pure bitumen. Its specific gravity is about 1.40. It is soluble in carbon disulphide, partly so in petrol ether, carbon disulphide, etc. It is often replaced in commerce by pitch, the residue of coal tar distillation.

Asphalt is detached in large blocks by the use of nicks and thrown into special recipients which convey it to the unloading base. The cavities made are soon filled by the influx of plastic material from below. Part of the asphalt undergoes refining at the place of extraction; the remainder is transported thence in the form of blocks.

This material still in a soft condition coagulates during transport and requires to be again hocked out on arrival. Refining is simply effected and comprises such operations as crushing, grinding, and riddling or pulverising with a hammer. Melting or even boiling is necessary for use in a compressed state. The asphalt is mostly heated in open tanks by means of steam coils, the water being driven off by steam.

The richer quality of rock is used for the making of asphalt mastic which is got from powder of the first or second order mixed with Trinidad bitumen 15-17 per cent.

Besides the system of extraction applied in the case of the vast deposits of Trinidad and Bermudas, Venezuela, etc., other deposits of lesser importance are worked either in mines or in the open.

Distilled dry asphalt yields oils which like those of schist serve as lubricants or combustibles (heating, lighting).

Artificial asphalt is only tar pitch mingled with powdered coke, limestone or sand.

**INDUSTRIAL USES**

The industrial uses to which asphalt may be put are many and varied. It is used as a paving material (macadam), employed in building as a "damp course", as a water-excluding coating for concrete floors and in the manufacture of roofing felt. In the making of asphalt roadways the material used is chiefly an asphaltic or bituminous limestone. Asphalt mastic is used for footpaths, floors, roots, etc., while machine bases for steam hammers, dynamos, and high-speed engines are made of asphalt concrete. Asphalt is also used as a constituent of artificial fuel (briquettes), of metal paints and varnishes—chiefly as a constituent of anti-rust coating materials. It is used for ships in this way and is a constituent of a number of extensively used commercial products of this kind (see article "Painting Industry"). For this purpose it is employed in a solvent (usually benzene) and after dilution is applied as in painting in a thin layer. Asphalt is further used as an insulator in the electro-technical industry, in photography, and for fixing bristles in the brush-making industry.

**TOXIC ACTION**

The action of asphalt and bitumen can be related to their geological origin. The presence in these products of certain mineral oils offers a ready explanation of the serious troubles they give rise to amongst the workers who handle them. Skin eruptions seem to vary roughly in relation to the specific gravity and the boiling point of the asphalt or bitumen. Cases of dermatitis in the form of acne affecting the whole body were noted, the victims being fourteen workers engaged in boiling asphalt. The skin had a yellowish tinge, the cause of which appeared to be the yellowish green fumes evolved during boiling.

In the large lake deposits the softer parts of the surface continually evolve gases consisting largely of carbon dioxide and sulphuretted hydrogen.

The fumes from boiling asphalt are noxious and unpleasant with a very strong odour, so that in factories and places where the product is boiled the asphalt kettle may be regarded as a source of discomfort. Open pans for heating asphalt should therefore be avoided and all fumes generated should be absorbed by a condenser.
Asphalt used in the brush-making industry can be very satisfactorily replaced by shellac (gum-lac), resin, linseed oil or any similar product. It must be admitted that cases of poisoning reported amongst workers using asphalt coating preparations (ships, metal reservoirs, etc.) are due rather to the solvents (benzene derivatives, phenol, etc.) than to the asphalt itself.

Hygiene

All measures enforced for the prevention of fire should be applied not only in the production of asphalt and bitumen but also in all branches of industry where it is used. Grinding and pulverisation should be effected in closed apparatus with an efficient exhaust system. Depots should be well isolated from other buildings. Exhaust hoods should be installed over the boiling kettles and steam and fumes should be condensed as the product liberates volatile empyreumatic substances such as ammonia and hydrosulphuric acid.

Legislation

In Canada (Quebec) boys under sixteen and girls under eighteen are excluded from preparation of asphalt.

In the Netherlands skin diseases such as eczema, dermatitis, cancer of the skin, cancerous ulceration, peripheral paralysis, ulceration of the cornea, and conjunctivitis caused by asphalt and products containing it are listed for compulsory notification.

Epitheliomatous cancer, ulceration of the skin and of the corneal surface of the eye due to bitumen are subject to compulsory notification in France and Great Britain, and compensated as accidents in Germany, Great Britain, and Minnesota and New York (U.S.A.).

Atropine (Daturine)

The alkaloid (formula: \( C_{35}H_{23}NO_3 \)) is extracted from the roots of belladonna and ripe seeds of stramonium. It should, however, be noted that it is not previously present in these, but is formed during the process of extraction (as the effect of the dilute alkalis), in consequence of a molecular transformation of another alkaloid isomer, hyoscyamine. Its characteristic action of dilating the pupils is well known. Herxheimer found in 1912 cases of eczema amongst workers handling atropine for the preparation of apo-atropine. In one case of atropine poisoning, tetanus was also reported.

Kruger, of Dresden, in 1925 met with eczemas localised on the hands, arms, neck, and face of workers in a factory for production of chemical products. The workers complained also of headaches, insomnia, and sensation of heat (fever?); these phenomena persisted for a long time after the workers had ceased work. The enquiry led to the conclusion that the symptoms were caused by the alkaloid preparations and in particular by atropine emetine and veratrine, while emetine was the principal cause of the dermatitis affecting the workers. Kruger found, on the other hand, that the workers who prepared the atropine suffered from dilatation of the pupils. Further, they were almost unable to read after quitting their work. They complained in addition of dryness of the mouth and of vertigo.

Auramine

This synthetic organic colouring substance [formula: \( (\text{C}_8\text{H}_8\text{N}_2\text{H}_2)\text{CNO}_3 \text{HCl + H}_2\text{O} \)] is got from hydrochloride of imido-tetra-methyl-diamino-diphenyl-methane.

Not easily soluble in cold water, auramine is soluble in hot water or acidulated water or in alcohol.

It is used for dying wool, silk, paper, leather, cotton (mordanting with tannin), etc.

It should be remembered that in course of its preparation the workers are exposed to the action of fumes of ammonia and sulphuretted hydrogen, and that it is not improbable that cases of poisoning by nitro and amino derivatives are connected with this colour group rather than with any other.

When the auramine is prepared using as the starting point Michler’s ketone, carbon oxychloride is used.

See also article “Tumours”.

***
Aurantia (Emperor Yellow)

This synthetic colour (formula: $(\text{C}_6\text{H}_4(\text{NO}_2)_3)_2\text{N.NH}_3$) is a sodium or ammonium salt of hexa-nitrodiphenylamine in the form of reddish brown crystals soluble in water. Heated on a sheet of platinum, aurantia burns brilliantly; it only explodes when present in large quantities.

It is used for dying orange-yellow wool, silk, leather (in an acid bath), shoes, and other yellow products dyed yellow and sold cheap.

During preparation of aurantia the workers are exposed to ammonia fumes. Hamilton noted two severe cases of pulmonary oedema amongst workers engaged in the manufacture of aurantia and indigo.

Aurantia gives rise to great quantity of small vesicles in close formation and appearing symmetrically on the palm of the hands (cases cited by Radcliffe, Crocker, Moser, Segueira, etc., and by P. White), attributed at least in part to the bad habit of cleaning the hands with chloride of lime.

Crocker reports that the dermatitis found amongst dyers is due to the use without precautions of a sponge soaked in the colouring solution and then applied to the article to be dyed.

Aurine (Rosolic Acid)

Aurine is a colouring substance derived from tar of the triphenylmethane group, erroneously called rosolic acid, for it is chiefly composed of para rosolic acid $(\text{C}_6\text{H}_4\text{OH})_2\text{C.C.H}_3\text{O}$. It is got by heating concentrated sulphuric acid with oxalic acid and phenol. In the crude state aurine is very impure and has a brownish green colour, being insoluble in water, soluble in alcohol, to which it imparts a yellow colour. It is used for lakes employed in dying carpets, paper, etc., for varnishes with an alcoholic basis (for metals), and as an indicator in chemical analysis, etc.

It should be recalled that its sodium salt — yellow corallin — may contain arsenic, according to the process followed in its manufacture. Another derivative, chrome violet or chrome ruby, is used for dying violet, cotton, mordanted with chrome for printing material, etc.

This substance only causes dermatitis which, in general, follow a benign course.

Aviation or Aviators' Sickness

The human body cannot with impunity ascend to great altitudes, often rapidly attained, and from which the descent especially is too rapidly effected. While definite symptoms are experienced by those who climb high mountains (mountain sickness), still more marked when ascending in a balloon, these become even more important in flying.

Quite a train of rather complex symptoms are comprised under the name of "aviation sickness". When repeated and under certain conditions they may induce a state of physical and mental overstrain.

Running parallel with physiological researches on the effects of flying, there has developed study of the pathology of flying, that is, of the nervous phenomena noted among aviators, during or after flying. These are of a transitory nature or more lasting when excessive fatigue due to piloting has also been endured.

Certain authorities, among others Galeotti and certain English experts, take the view that the clinical picture, in future to be referred to as "aviators' sickness", is not really a new malady added by the invention of the aeroplane to the "ills which flesh is heir to". In other words, no specific malady results from flying such as can be differentiated in any essential way from maladies provoked by causes analogous to those which occur in flying.

PATHOLOGY

The symptoms as described by those who allege there is an entity — aviators' sickness — are very different: "descent sickness" (Herlitzka), which befalls pilots and passengers; symptoms of neurasthenia following long flights, high altitude sickness analogous to mountain sickness, although no absolute identity exists between the two (it attacks aviators generally at or above a height of 5,000 metres).

In rising, at a height varying according to season and conditions of ascent, a feeling of cold is felt. First there is dryness of the mouth and nasal cavities, accompanied sometimes by slight headache, and sore throat necessitating efforts of swallowing.
Apparent hardness of hearing occurs, and this is more marked in foggy or cloudy weather and gives rise to a sensation of buzzing due to the noise of the motor.

Later, buzzing in the ears is felt, which may come on fairly soon according to the type of motor employed, rapidity of ascent, action of the wind, and internal injury.

Respiratory distress ensues, characterised by air hunger, short, weak and difficult inspiration, and easier expiration which readily disappears in coming down but a very little in height; the respiratory rate is increased as a result of the altitude, etc. Only when the height is great (about 5,000 metres) does respiration become difficult with breathlessness exaggerated by the muscular movements, and the cold. Occasionally Cheyne-Stokes breathing is observed (constant during sleep at high mountain elevation — Mosso).

As soon as the earth is left behind, the heart begins to beat more rapidly but without palpitation. The pulse is rapid and small Blood pressure (systolic) increases regularly especially in the first 500 metres; when planing is done it tends to become stabilised and return to the point at which it stood on leaving. The diastolic pressure on the other hand tends to get less, but also to revert to the point at which it was on departure, when horizontal flying is engaged in.

Sometimes peripheral congestion, especially of the face, occurs (peripheral vaso-dilatation following on original vaso-constriction), due to the cold — little observed now that aviators dress so much more suitably. It comes on mostly at about 4,000 or even at 1,500-1,500 metres if precautions against cold are not taken.

Slight frontal headaches when wearing a helmet cap with throbbing of the temples may appear at 2,000 metres, sooner if the ascent is rapid, and sooner still in novices than in trained flyers. Generally it is not troublesome before reaching 5,000 metres.

Nausea and vomiting, feeling of distension of the stomach, sea-sickness (in eddies of hot and cold air) are sometimes very intractable, especially when affecting tired persons and those suffering from intestinal atony.

At a high altitude voluntary movements are more clumsy, worried, nervous and jerky. Control is lost over the voluntary muscles, sometimes the fingers tremble nervously, there is tingling of the hands and feet, lowering of sensibility and of the fineness of the sense of touch. Cold, breathlessness, tachycardia, sun-glare, and troubles of hearing, nervous strain and fatigue, suffice to explain these motor troubles.

At about 5,000 metres a feeling of torpor, listlessness and sleepiness may come on. At first the effect on the nervous system, at slight elevations, shows itself in excitement followed by a feeling of well-being which again is followed at greater heights, by diminution in the power of fixing the attention; sense of distraction increases, and visual appreciation of things leaves much to be desired. Ideas come slowly, accompanied sometimes by derangement of intelligence, of memory, of judgment or a feeling of weakness.

In full flight aviators may be seized with sudden malaise. Cases of conjunctivitis and pterygion are fairly frequent, especially when the goggles are poor. Binocular vision may be interfered with at high altitudes. In many otherwise normal subjects diplopia appears, due to fatigue from continued convergence of the pupils, troubles of the nerve supply of the extrinsic muscles of the eye (abduction, adduction, elevation).

The imperious desire to micturate during the flight, which comes on at about 1,800 metres, is due to several factors: lowered atmospheric pressure, cold, urinary toxic action, vibratory action of the aeroplane, psychical emotional tension.

In horizontal flight when a high altitude has been reached, apart from effects related to length of the voyage, the different sensations just referred to seem to diminish; this fact is due to the establishment of physiological equilibrium to the new surrounding conditions followed by acclimatisation rapidly acquired.

During the descent (done by planing or direct descent) the sensations experienced are the stronger the more rapid the descent, and the latter is the more dangerous the greater the height from which it is made. The phenomena observed come from physiological disequilibrium of the organism and emotional nervous causes.

At the moment of the descent the tired novices and pilots may be seized with emotional disturbance from which even the strongest may not be exempt; fear of short duration, a feeling of emptiness, thoughts and visions of death conjured up by the rapidity of the fall (60, 90, 150 km. per hour: as e.g. 3,000 metres in three minutes; 2,585 metres in 1 min. 40 sec.). The flyer always has a disagreeable feeling.
of falling the moment the aeroplane commences to point downwards. The breathing, especially inspiration, seems to stop for a moment; it returns after a brusque inspiration, then according to the rate of the descent, it regains its rhythm; but this progressive return has not become complete on alighting on the ground.

The heart, momentarily slow, beats strongly, then quickens and palpitation increases with the rapidity of the descent. The aviator has a sense of constriction, sometimes slight, but capable of feeling like a burn, accompanied by a sensation as though his temples were bound. The pulse slows down and becomes more regular and fuller. The systolic blood pressure diminishes and may get lower than it was at the start; the diastolic on the other hand increases during the descent. Hearing again becomes difficult; the feeling of fullness and of auricular tension reappear, followed by buzzing, salvoes or hammering, whistlings, neuralgias, tearing pains, acute pricking sensations, intolerable pains unaffected by swallowing, which bring about mistaken sensations as to equilibration (faulty impression of speed), rendered so much the more dangerous as the eye loses momentarily the power of judging distances, which the altimeter may fail to indicate accurately.

These sensations, which last during the whole of the descent, seem even to become more intense in the course of the first few minutes after landing; they do not appear unless the descent has been a forced one (thousand metres per minute). In such cases there is great inclination to fall asleep (imperious at times), sensations of torpor, of confused thought, with a state of faintness (relatively frequent especially in the case of very rapid descents, or in that of aviators who carry out tricks, or of old, tired pilots), sometimes loss of consciousness (a probable cause of a large number of unexplained accidents and deaths of many aviators: Chavez, Hoxsey, Madiot), very marked fatigue (slow, voluntary movements, lazy, clumsy movements, nonbalance, of which some aviators are aware); impossible to resist on the part of certain aviators when run down is the imperious desire to return as quickly as possible to the earth (earth's attraction).

If the descent is slow (3 to 4 minutes per 1,000 metres), only slight buzzing in the ears, a feeling of auricular fullness, and slight oppression are experienced.

At greater speeds the recompression is very badly borne, especially in the last few thousand meters.

On landing may be noted slight incoordination, with, occasionally, markedly uncertain movements, a whim to jump out of the machine, a heavy although firm step, sometimes shaky, drunken gait, of the cerebellar type, especially after a long flight, febrifugal trembling of the limbs, transient nervous excitement, manifesting itself in joy and satisfaction experienced from the journey.

The effects on the cardio-vascular system are much more important. The cardiac movements do not regain their normal rhythm rapidly and sometimes cardiac insufficiency is prominent. Excessive systolic pressure with diminution of the amplitude of the oscillations is a habitual manifestation in aviators descending from high altitudes, especially when the descent is rapid. The systolic tension, which lasts for a few hours, is notable in trained pilots; it is less so in tired subjects or in those suffering from palpitation or very rapid pulse; it does not occur amongst aviators flying at moderate heights. The systolic pressure shows an almost need to increase. Some times it falls after a flight at low altitude.

Frequently headache lasts for some hours; an imperious desire to micturate comes on after landing (diminished secretion follows after a rest); a feeling of great fatigue with need for deep sleep is felt. Beginners suffer from backache due to the greater strain placed on the muscles of the abdomen.

These signs diminish in the following twelve to twenty-four hours, especially after deep sleep, though they may increase and persist longer after a rapid descent.

Occasionally excitability of the generative organs is diminished (the more so the longer the flight) and sometimes even a transient impotence occurs (one case lasted three months); in other cases muscular weakness, loss of cutaneous sensibility, exaggeration of tendon reflexes, a slight hyperglycaemia are found. Lesions of the middle ear, which may in time overtake aviators, are set up partly by the disagreeable noise of the propeller, partly by the variations in atmospheric pressure (see later).

The clinical forms vary from one person to another. Thus, the signs would seem to differ according as pilots or army observers are in question. Pilots are not emotionally affected, while the observers are; it need not be insisted on that aviators flying at night are more affected by
symptoms explained by extreme fatigue, ennui, excessive nervous tension from piloting and locating the position.

An enquiry among American flyers at the front brought out that 33 per cent. had not been at all inconvenienced, 18 per cent. had suffered from respiratory distress, 10 per cent. from cold and respiratory distress, 20 per cent. from headache, 12 per cent. from physical and mental depression.

Headache in aviators generally appears at altitudes higher than those reached in climbing, but lower than those reached in balloons. Malaise among them can be distinguished from that of mountaineers by the presence of vaso-motor reactions with hypertension, vertigo, headache, somnolence following ascents, cough, especially when landing and sometime afterwards. Further, no immunity such as occurs with mountaineers is found among flying men.

The symptoms referred to among aviators are very liable to recur if they do not take sufficient rest. Gradually a state of overstrain develops, which may appear in two forms — one physical, the other mental — or both may develop simultaneously.

**Physical overstrain** among aviators has nothing specially distinctive about it. At the same time because of the cardio-vascular overstrain, fatigue is apt to come on early, last longer, and attack the heart muscle more rapidly. It shows itself in cardiac asthenia which subjectively appears as intense lassitude and extreme fatigue, objectively by lowered systolic and especially lowered diastolic pressure, not only on landing, but particularly after the flight when resting.

Sometimes tachycardia is noted, and even increase of the heart's volume has been described as being pronounced in those who had been engaged actively in the capacity of pilots over a more or less lengthy period.

These symptoms which are accompanied by instability in the arterial pressure disappear after some weeks' rest except in severe cases which may last for several months.

Among general symptoms are seen a tendency to become thin, loss of fat about the face (cheeks, nose, drawn features), a roughened dry skin (hyperpigmentation, resembling shagreen, rough to the touch), dermographism, change in temperament, irritability, restlessness, indecisiveness, etc. Intellectual or physical work may become irksome, scintillating scotomas may be present, lack of appetite, difficult or slow digestion, constipation alternating with diarrhoea; insomnia or, on the other hand, sleep heavy and deep, constantly disturbed by dreams and nightmares; waking up often with a feeling of great tiredness; muscular pains and intense but relatively transient headache, exacerbation of physical pain.

Some part of the *psychical fatigue present in aviators* is due to physical exhaustion; the rest to brain fog incurred in flying—emotional strain, strain on the attention and will which may weaken at any given moment. The part played by the nervous factor comes into prominence in persons who experience exacerbations of these sensations or other abnormal sensations when they change aeroplanes or in those who have had to make a descent by parachute. Suddenly restlessness, loss of confidence, the feeling of distress supervenes, leading to aviators' nervousness.

One of the first signs is difficulty in appreciating distance and the bad landings which are a consequence. Diplopia comes on with diminution of retinal sensibility and of the muscles of accommodation.

The neurosis of aviators, peculiar to pilots, although its picture is not characteristic and some authorities express doubt about it, presents the same symptoms as those met with in the victims of neurasthenia, and psychasthenia. In forms recalling the former at the end of a period during which he has been expending the maximum energy, the pilot notices his working capacity, resistance to altitude, down in altitude during the flight by emotional disturbance, modifications in metabolism under the influence of anoxaemia, and by the changes brought about in the functions of the kidneys and suprarenal capsules. Jegerow, of Moscow, has described (1920) the results of his inquiry into the heart's action in 142 aviators on active service. His conclusion is that his examination brings out for a fairly large number of pilots, an insufficiency in the cardio-vascular functions.
and duration of flight diminish, the considerable nervous tension brings on depression, which, at first slight and transient, may become persistent and profound. The effect or distressing influence of altitude or impressive incidents or accidents during flying flourishes in such a soil without possibility of reaction. The resulting emotivity may be rendered dangerous on account of the illogical reactions so determined.

In psychasthenics the same symptoms are noted as in neurasthenics except that, in addition, impulses and phobias may be present. Constitutional neurasthenics, therefore, ought, at all costs, to be eliminated as in their case flying so often brings out latent abnormal psychical reactions. Nevertheless, nervous exhaustion is not a morbid condition to which the majority of aviators are subject.

English and American authorities are accustomed to refer to the existence of a flying temperament impossible to define medically, but enabling some persons, with recognised clinical symptoms, to execute more or less well certain functions of flying.

While the pathogenesis of psychical and physical overstrain and of aviators' neurosis is easily explained by the recurrence of accidents, it is not so with flying sickness, for which numerous theories have been put forward. Thus there is the theory of anoxaemia (Jourdainet, Bert; see article "Air: Diminished Pressure"), according to which lowered atmospheric pressure exerts its influence because it diminishes the partial pressure of the oxygen, which becomes lowered in proportion as the ascent is made (it is the failure to absorb oxygen which is at the root of the sickness trouble among flyers); the theory again of fall in atmospheric pressure; that of acapnia (Mosso) and the theories invoking distension from intestinal gases (pushing up the diaphragm interfering with thoracic respiration), or a diminution in pleural pressure (occasioning stasis in the pulmonary venous system), or further inability to aspirate the blood into the lungs; finally there is the view that fatigue is the cause, which finds some confirmation in the slower appearance of altitude sickness among balloonists than in alpine climbers and of its occurrence among flying instructors who have been out several times in the same day even at altitudes less than 1,500 metres in two-seater machines which involve hard work.

Analysis of the troubles arising in descending (aviators' sickness, as described by Cruchet and Moulinier) brings out the effects on the ear and general state of health. Herlitzka explains them as due partly to tubal insufficiency, that is, insufficient opening of the eustachian canal and failure, therefore, to equalise the pressure on both sides of the drum, which fails then to vibrate properly, and partly to abnormal excitation of the vestibular apparatus of the semilunar canals. Two very important functions depend on the ear: one tubal, peculiar to the middle ear (rapid modification in pressure); the other vestibular, adaptation of the three dimensions of space, the sense of acceleration and the regulation of muscular tone.

The unequal pressure on the two sides of the membrana tympani explains very well the ear troubles, the giddiness, and the vomiting which occur in rapid descents. But the general and circulatory phenomena do not conform to such an explanation. The hypothesis put forward by Cruchet and Moulinier, namely, transitory increase in blood pressure to explain a clinical picture which other authorities have not been able to find, even in pilots descending at the rate of 1,000 metres in 2 seconds, would appear to be insufficient in view of the smallness in variation of such a pressure. Herlitzka thinks that the cause of the trouble in question is to be sought in the inner ear. A rapid descent will provoke and increase excitation due to the inertia of the small bones of the middle ear, and when this is great, in addition to the subjective symptoms, sympathetic and para-sympathetic reflexes are also set up, with alteration in the circulation resulting in some cases in fainting, tonic spasms, in the characteristic positions of the limbs.

The sickness from descending is explained by Herlitzka as due to two superimposed factors: auricular disturbance from unequal pressure on the drum and altered position of the latter with hyperaemia, defective hearing, pain, etc., and to the changes affecting the vestibular apparatus brought about by the movement of the body in rapid descent. Sleepiness is said to be due to several factors, such as nervous fatigue, wind, diminution of atmospheric pressure, etc.

It is unnecessary to insist on the influence which various individual lesions may play (renal insufficiency, indigestion, heart weakness, etc.). Cold can only serve to increase such unfavourable influences because while
it provokes torpor and fatigue it also weakens the physical forces and moral energy by inducing an imperious demand to sleep. Cold, which is extreme at high altitudes and is influenced by the rapidity of flight, the position of the engine, etc., not only sets up congestions fatal of themselves, or from the falls they bring about, but is further a cause of fatigue of the heart and consequently of high blood pressure. The wind, against the action of which civilian aeroplanes are to-day well protected, plays an important role in badly protected military machines. Aviators and observers complain of headache, respiratory trouble, nausea, vomiting, etc. Probably wind has a reflex action on the respiratory rhythm, the centre for starting such reflexes being situated in the mouth. In the opinion of some authorities early cardiac fatigue due to necessary adaptation to fluctuations of atmospheric pressure and the physiological consequences of this, the transient anaemia of different organs offer sufficient explanation of the bulk of the troubles and symptoms met with in the nervous system, the lungs and the kidneys. So far as the kidneys in particular are concerned, auto-intoxication would add to the malaise known as aviation sickness (Cruchet), which is said to be only the first stage in the aviation sickness of Ferry, and characterised by a transient central ischaemia and slight renal auto-intoxication. If the auto-intoxication continues, then a syndrome of renal insufficiency shows itself, more or less severe and lasting. If the aviator does not take rest, this passes into the second stage, corresponding to the asthenia of aviators.

Some authorities seem finally to attribute much importance to the emotivity of the subject, to his physical and psychical constitution, while others attribute to auricular damage most of the malaise felt by aviators. As to the breakdown of some pilots who fall short of what they have expected to be able to do, they believe this must be ascribed to general weakness, cardiovascular and renal, first physiological, then pathological, with low tension, or as the result of general nervous deficiency, especially associated with slow and irregularly timed psychomotor reactions or, eventually, defect of the sympathetic nervous system.

Employment of aviators in scattering insecticides on trees, etc. (compounds of lead and arsenic, toxic gases, etc.), exposes the pilots to risk of poisoning.

### Statistics

**Aviators’ Sickness**

Distinction in flying accidents must be drawn between civil and military aviation. In the latter accidents are much more frequent, due to the machines used (in which speed is often sacrificed to safety) and to the conditions under which flying is done. In civil aviation, too, distinction must be drawn between apprenticeship, piloting, and ordinary flying. The following figures are particularly interesting from this point of view:

**France.** — For all the routes:

<table>
<thead>
<tr>
<th>Number of</th>
<th>Number</th>
<th>of km.</th>
<th>passengers</th>
<th>flown</th>
<th>included</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920</td>
<td>633,069</td>
<td>1,771</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1921</td>
<td>903,455</td>
<td>10,619</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1922</td>
<td>7,293,368</td>
<td>9,562</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1929</td>
<td>3,877,186</td>
<td>11,633</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>194 (first eight months)</td>
<td>2,426,086</td>
<td>11,619</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The same aerial routes at the end of the first eight months of the year 1924 give:

1 accident per 2,426,086 km.
1 fatal accident per 808,895 km.
1 accident per 3,873 passengers

The following figures for the year 1923 of the airways companies are also interesting:

<table>
<thead>
<tr>
<th>Coeff.</th>
<th>Flights</th>
<th>Pil-</th>
<th>Passengers</th>
<th>gers of safety (per cent.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Franco-Romanian Company</td>
<td>986</td>
<td>1,091</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Hungarian Airways Company (Budapest-Warsaw)</td>
<td>155</td>
<td>368</td>
<td>93.3</td>
<td></td>
</tr>
<tr>
<td>Hungarian Aero-Express Company</td>
<td>124</td>
<td>204</td>
<td>93.9</td>
<td></td>
</tr>
<tr>
<td>Austrian Airways Company (Munich-Vienna)</td>
<td>232</td>
<td>396</td>
<td>86.5</td>
<td></td>
</tr>
</tbody>
</table>

In 1924 (to 31 September) the figures for the Franco-Romanian Company were as follows: kilometres covered, 189,279; passengers, 414; no accidents.

**Great Britain.** — From 1 May 1919 to 31 March 1920, 37,821 aeroplanes had flown about 681,859 miles and carried 67,940 passengers. The flights with passengers totalled 18,096 hours. Fatal accidents numbered 4, non-fatal 11, which gives nearly 1 accident per 2,872 miles flown and 1 fatal accident per 195,000 miles.

The percentage of accidents to the personnel in charge can thus be shown:

| Pilots killed per 1,000 hours in flight | 0.415 |
| Pilots injured | 0.294 |
| Passengers killed per 1,000 passengers carried | 0.014 |
| Passengers injured per 1,000 passengers carried | 0.176 |
| Passengers killed per 1,000 hours of flight | 0.065 |
| Passengers injured | 0.063 |
**AVIATORS’ SICKNESS**

**United States.**—From 17 September 1908 to 1 April 1914 462 aviators had met with accidents. In 1920, 1,000 aviators spending 74,900 hours in flight met with only 312 accidents distributed as follows:

<table>
<thead>
<tr>
<th>For pilots</th>
<th>For passengers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uninjured</td>
<td>217</td>
</tr>
<tr>
<td>Slightly injured</td>
<td>46</td>
</tr>
<tr>
<td>Severely</td>
<td>12</td>
</tr>
<tr>
<td>KILLED</td>
<td>34</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>312</strong></td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Uninjured</td>
<td>217</td>
</tr>
<tr>
<td>Without passengers</td>
<td>84</td>
</tr>
<tr>
<td>Slightly injured</td>
<td>46</td>
</tr>
<tr>
<td>Severely</td>
<td>10</td>
</tr>
<tr>
<td>KILLED</td>
<td>12</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>312</strong></td>
</tr>
</tbody>
</table>

The Manufacturers’ Aircraft Association from 1 January to 30 June 1921 had a total of 3,250,000 miles of flight with 58 accidents, of which 10 involved 14 deaths, 20 with injuries and 18 without accident to the occupants—a proportion of 1 fatal accident per 325,000 miles flown.

The Aero-Marine Airways Company, in the fourth year of its existence, after having carried 30,000 persons over 1,610,000 kilometres with only 1 serious accident, could provide, in 1922, a 100 per cent. service and in 1923, 99 per cent.

In Italy, the flying accidents in the army in 1924 numbered: 0.46 per 100 hours of flight in January 0.03 per 100 hours of flight in February 0.056 per 100 hours of flight in August

With a total of 108,000 km.

In Switzerland the statistics of aviation were as follows:

- Number of flights: 19,952
- Total duration: 5,900 h. 11 min.
- Kilometres flown: 660,500
- Number of falls: 16 | (with destruction of aeroplane)
- " of deaths: 1
- " of severely injured: 1
- Bad landing due to accident to the aeroplane or bad weather: 42

The statistics of commercial flying in the same year showed that for 3,500,000 km. flown there were 30 accidents, and that in 1923, for 3,900,000 km., only 12, with a single fatality.

At a recent conference (1926) in Paris, Volmerange discussed the question of safety.

Of 10 accidents, 8 affect military aeroplanes, one only transport, the tenth being traceable to a civil aeroplane of another kind.

To appreciate the degree of confidence which aerial transport deserves, this expert proposes to establish a safety coefficient proportional to the number of kilometres flown to one fatality or seriously injured person. As the value of this coefficient he proposes to take the number of hundreds of thousands of kilometres traversed per victim. Safety would be designated by the figure 2.

In 1912 it was only 0.9, whilst for the period 1923-1924 it reached the figure of 3.3. Safety, therefore, had been more than tripled in the last three years and the figure for 1926 ought to be about 5.5.

To translate these figures in concrete fashion, it would be safe to say that today the world would have to be encircled eight or nine times in an oceanic aeroplane before one chance in two of being seriously injured arose.

The passenger service is not submitted to the same exigencies of punctuality as the postal service. If flights were stopped during foggy weather accidents would be considerably reduced in number, as the percentage due to poor visibility is 20 per cent. Most progress, however, is to be sought in improvement of the aeroplane itself as more than 5 per cent. of the accidents result from the machine itself flimsy and nearly 30 per cent. of the victims of civil aviation perish by fire.

Motor troubles have been reduced very rapidly since 1923. Thus the reduction in 1924 was from 45 per cent. to 22 per cent. and to 7 per cent. in 1925. Skill of the pilots is the principal cause of this happy result because the percentage of accidents to the aeroplanes themselves has only diminished in the same period from 30 to 27. Half the stoppages are due to accessory parts of the engine (escape from joints, radiators, etc.). Fifty per cent. of the stoppages of the engine proper are due to breakages of mechanical parts.

The following statistics show that selection of candidates for aviation, made by the most complete methods which science knows to-day, has a fundamental bearing on the prevention of flying accidents.

**In Great Britain in 1916, 90 per cent. of the accidents were due to faulty piloting. After utilising rational methods of selection the percentage fell in 1917 to 65, in 1918 to 20, and in 1919 to 12.**

Further proof is furnished by the number of rejections following the physiological examination.

Thus, in France, for example, of 4,645 candidates examined between 1 May 1921 and 1 December 1923, 1,726 were found unsuitable for flying. Among the candidates rejected (38.2 per cent.) 11.7 were due to ocular defects, 6.4 to chest affections, 5.6 to diseases of the circulatory system, 4.9 to troubles of hearing and equilibration, 3.2 to general constitutional defects, 2.8 to urinary affections, 0.9 to nervous affections, 0.5 to digestive derangements and 2.5 to various causes.

In the United States 29.3 per cent. of the candidates were found unsuitable for flying, and of these 5.9 were due to ocular defects, 2 per cent. to hearing and equilibration, 1.5 to circulatory, 1.2 respiratory diseases, 0.8 to diseases of the nose and throat, and 0.4 to diseases of the urinary passages, etc.

C. F. Shook (1925) states that during three years, of 300 candidates in Great Britain, 23 per cent. were rejected for permanent defects which could be thus
classified in order of frequency: defective sight (110), physical defects of the nervous system, diseases of the ear and nasopharynx.

Defects in equilibration were less frequent (8). Among other causes of rejection were: increased blood pressure, poor chest expansion, hernia, haemorrhoids, asthma, rheumatism, etc.

Examination of the candidates for the Italian army and navy-air service carried out in the psycho-physiological services in Turin, Rome and Naples in 1917 and 1918, gave the following results:

<table>
<thead>
<tr>
<th>Number of candidates</th>
<th>Number of rejections</th>
<th>Percentage of rejections</th>
</tr>
</thead>
<tbody>
<tr>
<td>14,580</td>
<td>4,733</td>
<td>33.14</td>
</tr>
<tr>
<td>100</td>
<td>33.14</td>
<td></td>
</tr>
<tr>
<td>9,547</td>
<td>4,733</td>
<td>66.86</td>
</tr>
</tbody>
</table>

The causes of rejection were:

1. Excessive nervousness: 292 cases (4.00%);
2. Affections of the muscular sense: 44 cases (0.92%);
3. Defective reaction time: 297 cases (4.79%);
4. Heart affections: 885 cases (13.70%);
5. Albinism: 118 cases (2.49%);
6. Defective sight: 1,668 cases (26.05%);
7. Daltonism: 144 cases (2.35%);
8. Defect in vestibular apparatus: 302 cases (4.88%);
9. Defective nutrition: 354 cases (5.86%);
10. Thyroidism: 99 cases (0.74%);
11. Defects in ear, throat, nose: 406 cases (6.75%);
12. Nervous exhaustion: 179 cases (2.95%);
13. Various: 292 cases (4.67%);

Total: 4,733 cases or 100.00%.

In Russia a committee attached to the principal sanitary and war administration carried out a series of enquiries, in 1921, into the question of the safety and selection of aviators, of which the principal are due to Professor Schpilrein.

**DIAGNOSIS**

The diagnosis of aviation sickness is based especially on the vasomotor reactions with lowered tension, vertigo, headache, somnolence following on flights and showing itself most frequently on the ground and some time after descending.

**HYGIENE**

Aviation sickness, and especially the asthenia from strain, can be avoided by progressive education carefully controlled and by adopting carefully considered hygienic measures.

Protection is required against cold, and after reaching a height of 2,000 metres recourse should be had to oxygen inhalation, or, better, a mixture of carbon dioxide and oxygen (Mosso's method; Garsaux's apparatus). 1

While practical necessities require that flying be done at heights above 6,000 metres, care must be taken to protect the pilots against the ill-effects from high altitudes. Automatic administration of oxygen, or still better of a mixture of oxygen and carbon dioxide, so arranged that a greater amount is supplied in proportion as the height increases, is important as a protection. The Germans recommend liquid oxygen, and many types of apparatus have been devised by Garsaux.

Cotton wool should be placed in the ears. Swallowing should be practised to reduce pain and the buzzing in the head.

The ascent and descent should be made slowly. If the descent is made in sections the painful sensations on coming down are lessened, especially in the last 1,000 metres. The desire to come straight down should be resisted (earth's attraction). A sportsmanlike attitude and behaviour should be observed and excess of whatever kind avoided.

Regular periods of rest should be taken three weeks every four months or still better a certain number of hours after every flight.

Periodic medical examination should be enforced with a view to determining the aviator's state and suspending those showing signs of over-fatigue.

Pilots should be selected from those who are between 18 and 25 years of age; persons over 35 should be discouraged from entering.

Physiological examination of aviators yields only negative criteria for purposes of selection, that is, it is not enough to say that a certain individual will make a good flyer merely because he has sound organs which function properly. Nor will it eliminate the unfit. On the other hand, the psychological examination gives positive data to determine whether the candidate has the necessary psychical qualities demanded of rapid flying, can stand high altitudes, etc.

An examining station to-day would comprise:

A service for carrying out general medical examination with special reference to personal and hereditary antecedents, habits, success in sports, accidents, subjective symp-

1 These inhalations diminish the acceleration of the pulse produced by depression of the respiratory rhythm, as well as subjective pheno-

mena (headache, buzzing in the ears, etc.), but their usefulness depends on how they are taken. The partial tension of oxygen should be habitually equal to 21 per cent. The apparatus must be carefully regulated and frequently verified by competent persons.
toms, height, weight, other biometrical data, clinical data, morphological and endocrine state, etc.

A neurological service to determine especially the demeanour of the candidate, to test the coarse and fine muscular force, sense of space and position, estimation of weight, epicritic and protopathic sensation.

A physiological service to determine the psycho-motor reactions, emotivity (which varies with the psychical state from moment to moment), the external factors in candidates for piloting duties, well-trained and super-trained pilots, the psycho-sensitive-motor instability, etc.

An ear and throat service to analyse especially the functions of the vestibular apparatus and tracts, the permeability of the Eustachian tube, exact sense of position, etc.

An eye department to examine visual acuity to normal light, night vision, quickness of perception, effects of dazzle, the visual field, binocular vision, perception of depth, etc.

Other enquiries should also be made by the medical examiners as to circulatory, renal and motor functions, etc. In Great Britain, on returning after sick leave a determination of the haemoglobin, enumeration of the red and white blood cells, of the parasites; a culture of the blood is made for the typhoid and paratyphoid A and B, dysentery, Malta fever, etc.; a Wassermann test is made; the urine is examined for blood, pus, sugar, casts, bilharzia, tubercle bacillus, etc.

The following findings are generally considered to be contra-indications for the grant of an aviator's licence:

(a) Digestive troubles, especially gastro-intestinal atony, flabby abdominal musculature (brusque displacements of the aeroplane being capable of injury to the abdominal organs and so giving rise to syncope, or, at any rate, lipothymias the consequences of which may be fatal).

(b) Constitutional circulatory insufficiency, high blood pressure (which rapidly predisposes to cardiac insufficiency).

(c) Chronic lesions of the respiratory system; asthma, emphysema, old pleurisy with adhesions, chronic bronchitis, pulmonary tubercu

losis (flying may further reveal latent tuberculosis and cause it to develop rapidly).

(d) Nervous diseases such as tabes, epilepsy, affections of sensibility in general, and specially tremor, incoordination of movement, etc. The psycho-motor reactions of sight to visual, auditory and tactile stimuli must be exactly determined. Attention is paid to the consistency of response rather than the actual time value. It should be said that some authorities consider the psycho-motor tests as pre-eminently important, while others attach more weight to aptitude for flying, to variations in blood pressure, and respiratory rhythm.

(e) Affections and diseases of the ear; chronic otorrhoea, vertigo, buzzing in the ears, middle ear catarrh, undiagnosed otosclerosis; nose and throat lesions (enlarged tonsils, adenoid vegetations). Hearing should be carefully noted and sense of equilibration also determined by suitable turning tests.

(f) All affections of sight. The intrinsic muscles, the fundus oculi, the retina, refraction, visual acuity, even that of the effect of dazzle, night vision, quickness of perception colour vision, visual field, binocular vision, and, according to some, perception of depth, etc., should be submitted to minute examination.

Finally some authorities think that the Eustachian tube should be examined as to permeability, fine sense of position, dissociation of sensibility, degree of emotivity, and, in addition to all these tests, supplementary examination as to resistance to lowered pressure in a rarefaction chamber (resistance and at the same time functional state of the Eustachian tube).

Every method of physio-psychological and clinical examination as well as examination by X-rays should, therefore, be employed in the selection of pilots.

Most countries have organised special centres for psychological examination of candidates and for their periodical examination. Germany, Belgium, Denmark, the Netherlands, etc., possess such centres; France has nine, where periodical examination is made every six months, or after an accident or illness, and before resuming employment; in the United States there are 67 offices, and a special school for the medical officers of aerial navigation.
(at Mitchell Field, New York) forms a part of the medical flying unit; in Italy three centres and a fourth in preparation are charged with the medical control and with scientific research into matters connected with aviation.

In January 1925 the British Air Ministry published a pamphlet entitled The Medical Examination of Civilian Aviators, and in March 1928 another one entitled The Medical Examination of Civilian Aviators.

Further, it should be stated that in most countries aeronautical insurance companies have combined in a federation with the object of insuring against a greater number of risks and giving a more generous rate of pay in case of accident.

Generally military pilots insure themselves against accidents; in Czecho-slovakia, Italy, etc., the State intervenes to insure all of its pilots en bloc in the usual way with the grant of an indemnity in case of death or permanent incapacity (Act of 8 July 1925). An Order of 10 June 1926 of the Serbo-Croat-Slovene Kingdom insures the flying personnel.

Legislation

In general each country has laid down rules for guidance in the choice of pilots and drawn up a list of the disabilities and maladies which constitute incapacity and inaptitude for flying.

The Aeronautical Inter-Allied Health Union laid down in February 1919 certain views, and expressed the hope that an effort should be made to codify the different criteria to which expression was given to apply the medical conditions as to aptitude for aerial navigation are fixed internationally in the Convention of 13 October 1919, stipulating that the medical certificate necessary for obtaining a licence as pilot, navigator, or aircraft mechanic should be given in the different States by medical men specially appointed for the purpose.

The conditions of physical and mental fitness both for initial selection of the personnel as well as for the periodic medical examination (to be held every six months or before resumption of employment after an accident or illness) should be as follows: absence of all moral or physical damage which could possibly affect safety in aerial navigation; minimum age for pilots, 19 years; absence of wounds of surgical operation or deformities, congenital or acquired, making management of aircraft difficult; perfect vision and perception of colours; quickness of vision, not more than two diopters of latent hypermetropia; good accommodation; normal hearing, and normal vestibular apparatus without excessive or diminished excitability; absence of obstruc-

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See also Giornale di Medicina milit., 1919, No. 1, Rome (series on physiological studies); Gigiena Truda, 1923, Nos. 5 and 6, p. 90, and No. 12, 1925, p. 41 (in Russian); Nos. 133 and 137 of the Journal of the Japanese Medical Association, 1924, for the reports of TERASHI presented to the Sixth Session of the Japanese Medical Association in 1922; and for the extensive bibliography the Bibliography of Industrial Hygiene, published quarterly by the International Labour Office.

Prof. Herlitzka

(Turin).

Azines

Azines are organic bases called also by some “chinoxalines”. They occur generally in the form of yellow crystals and are only intermediate bodies in the manufacture of several important organic colours (safranines, indulines, etc.). The bodies of this series have the property of causing damage to the cells of higher organisms when they
are exposed to the action of light while remaining inactive in the dark. (See article "Anthraquinone").

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Azobenzene

Azobenzene (formula: C₆H₅N₂C₆H₅) is obtained by reducing nitrobenzene by means of a sodium amalgam, zinc and solution of caustic soda. It can also be prepared electrolytically, or by heating under pressure a mixture of coal and solution of caustic soda.

Other nitro-compounds may here be mentioned which are of some practical importance. They are obtained generally by reducing nitro-derivatives of the aromatic hydrocarbons or by oxidation of aniline and its homologues. These compounds are yellow or red substances and are insoluble in water. The most interesting are: azo-azobenzene (C₆H₅N₂O₂C₆H₅), hydro-azobenzene (C₆H₅NH.N₂C₆H₅), obtained electrolytically by the reduction of nitro-benzene; on boiling it with acids benzidine is formed (see that article); amino-azobenzene (C₆H₅(NH₂)N₂C₆H₅) with three isomers and their derivatives, used in the manufacture of synthetic organic colours.

The homologues of benzene, especially toluene, also yield a series of nitro-compounds, among which may be cited azotoluene (C₆H₅CH₃N₂C₆H₅), of which the para-isomer especially is used. It is obtained by reducing paranitrotoluene, or by treating paratoluidine with chloroform and chloride of lime.

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The diazo compounds are also analogous compounds, generally prepared by the action of nitrous acid on aromatic salts of the amines, amino-acids, etc. Thus, e.g. diazobenzene is obtained by treating a solution of aniline in hydrochloric acid with nitrate of soda at 0°C. (see article "Dyes"). These compounds are not very stable as they decompose readily, sometimes exploding and giving off free nitrogen. They are very important in the manufacture of artificial colours.

According to Stoeber, amino azotoluene has a chemiotactic action on epithelium which it converts very readily into Keratin. The ortho isomer is said to have an action even more powerful than scarlet red. These products are usefully employed in hastening a cure in cases of severe burns. Two cases of industrial poisoning have been reported, the symptoms being cyanosis, vertigo, effect on sensibility, delirium, coma, etc. (See articles "Benzene", "Toluene", "Xylene", etc.)

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Azo-Triphenylmethane

This acid colour — green — of which the formula is (H C₆H₅)₃C₆H₅ — is reported by O. Sachs (1911) to have caused warts (papilloma) on the face and arms of a painter who had manipulated it for a period of nine months. An English writer also (1912) has described an eruption on the fingers and hands in the case of a woman who had handled cloth dyed with azo-colours.
Bakelite

Under the name of bakelite, called after the inventor Bakélard, are comprised generally the synthetic resins obtained by condensation of a phenol and an aldehyde by heating the phenols (phenols, cresols, xylenols) with formaldehyde in presence of small quantities of bases or acids acting as catalysts.

The reaction takes place in two successive stages: by the first is obtained a product soluble even in a cold state in the different organic and plastic solvents, but which may, however, become hard and fragile by cooling, and which resembles in appearance colophane (A bakelite); the second stage transforms the A bakelite into a product insoluble in ordinary solvents, plastic when hot (B bakelite) or hard whether cold or hot (C bakelite).

The soluble resins are used in the preparation of varnishes resisting the influence of the weather and having a marked insulating quality in regard to electricity. The mixture of A bakelite with inert substances permits of the manufacture of many different objects employed for the most part in electric construction and in motor-car manufacture. Mixed with asbestos it is at present used in chemical apparatus (recipient, basins). Mixed with different colouring agents the resins are used in the manufacture of objects in imitation amber, ivory, etc., which can be manufactured in the same way as wood.

In one case studied by the Dutch medical inspectorate (1926) manipulation of bakelite was said to have caused very marked nervous troubles, amongst which the most noted was strong somnolence. During turning and polishing dust is generated which smells distinctly of phenic acid and it is to this product that the medical inspector felt justified in attributing the symptoms met with. Cases of dermatitis are of more frequent occurrence amongst workers handling bakelite. Sachs (1921) reported serious cases in Austria. He also calls attention to the fumes of phenol, formic aldehyde, and hydrochloric acid given off during the process which give rise to irritation of the mucous membrane (eye, respiratory passages) as well as of the skin (face, forearm).

The doctors at the formaldehyde and derivatives factory of Perth, Amboy, in the State of New Jersey (U.S.A.), have reported that bakelite acts as an irritant of the skin and that an affection known as bakelite itch is frequently met with amongst the workers. It would not, however, appear that manipulation of the finished product is the cause of injury (Hamilton).

Bakery Trade


The term "bakery", used in the widest sense, includes the making of bread, pastries and sometimes even biscuits.

It is true that in certain countries and in certain districts the introduction of machinery and of continuous ovens, the development of wholesale and semi-wholesale trade, and the application of legislative provisions, by greatly modifying technique in the bakery trade, have considerably improved working conditions from a health aspect. The baker's occupation, however, is nevertheless, in other countries and other districts, carried on in accordance with very antiquated methods and health conditions in such cases leave much to be desired. The statistics quoted later, certain of which are not quite recent (Epstein, 1908; Zadek, 1913), refer at times to countries which, in the interval subsequent to the publication of these statistics, have happily modified working conditions in the baking trade. They are nevertheless of value as presenting an estimate of the evils which threaten working bakers in certain countries which are still without improved methods of working.
BAKERY TRADE

TECHNICAL OPERATIONS

The conditions of bakery work are peculiar to the trade; as bread has to be consumed comparatively new, and as the customers require a different kind of bread in different localities, there are practical difficulties in organising production on a large scale. Thus there are three types of bakery, the small family bakery, the small bakery that employs outside labour, and the big bakery that uses machinery.

The first type is typical of country districts and of small towns and may even be found in big centres of industrial districts; it is represented by a bakery where the owner makes and sells his bread himself without the help of outside labour, and where either no machinery is used, or only a very limited amount.

A type of small bakery employing paid workmen is also very commonly found where some use is made of machinery, such as kneading troughs. Only big modern bakeries employ a large staff and up-to-date machinery.

The making of bread includes the following operations:

Preparation of the dough.— Different localities vary in their methods of bread making. Without entering into details which have no direct bearing on the hygienic conditions of labour, it is enough to note that fermentation of the dough is the essential operation in preparing some kinds of wheat bread; this fermentation generates carbonic acid, which gives a porous and elastic consistence to the crumb when baked. The method most often employed consists in mixing into the dough yeast or barric, just a piece of raw dough kept over from the day before, or else sometimes in aerating the actual water which is used to mix the dough.

The ingredients having been mixed, kneading follows either by hand or by machinery in kneading troughs. When kneaded the dough is left alone to "rise", which requires special conditions of temperature, etc. When ready it is divided by hand or by machinery, and thus every kind of shape is made according to the requirements of customers. Then it is weighed, moulded and passed on to be baked.

Oven work begins with stoking; when the oven has reached the required temperature, the workers begin to introduce the bread which is baked at a temperature of between 200° and 300° C. With old-fashioned ovens stoking has to be done in the same room where the baking takes place. The ovens are heated with wood or peat, with coal or coke; and before baking, the oven, which often has only one door, has to be cleaned out and stoked. For putting the bread into the oven and taking it out again a long wooden shovel is used, and the bread is laid right on the bottom plate of the oven. This is a very tiring process and not over quickly effected.

With modern ovens, heated by oil, gas, or even electricity, the heating chamber is separated from the chamber where the baking takes place. These types of oven make it possible to obtain a high temperature and to keep it regulated. An oven with a movable bottom plate, mounted on wheels and moving on rails, constitutes an important improvement, which makes it possible to put in, or take out, a batch of bread in three minutes.

The question of delivering bread is connected with its making. Bread is often sold in the shop, but is very often delivered at the home. The question of transport is of special importance for large bakeries, as many of them have branch establishments or depots, which must be regularly supplied first thing every morning.

SOURCES OF DANGER

It must be noted that any danger in the industry arises not from the actual raw materials handled, but from conditions of work; with regard to these conditions, it is impossible to compare small bakeries with large up-to-date establishments. As a matter of fact, all the sources of danger which exist in small bakeries have been almost eliminated from large ones.

The fact remains that under present-day conditions, while small and medium sized bakeries still predominate, in a certain number of countries, the chief sources of danger for the workers are represented by fatigue due to work, by the action of injurious or toxic products, and of high temperatures and close atmosphere; and, finally, by the conditions of life inevitably associated with the trade. The life of a working baker is certainly a laborious one, due to the nature of the work, the long hours, and particularly to night work.

When not effected mechanically, the operations of preparing the bread, kneading it and dividing it, call into play all the muscles of the body for a lengthened period. Putting the bread into the ovens and taking it out is very trying owing to the need for rapid action and to the exposure to radiant heat from the ovens, and also to the
posture which the workman is obliged to assume.

Particularly when done by hand, operations ancillary to baking, for instance, carrying sacks of flour, are also trying for they then call for strenuous effort. The transport of bread itself is tiring, even if a bicycle or a tricycle carrier is used.

This overstrain has a particularly bad effect on young workmen, who soon exhibit signs of chronic fatigue and exhaustion, and, in a short time, more serious organic troubles, such as heart disease and vascular troubles, deformities of the legs and body, hernias.

Another source of fatigue is the long hours of work, which formerly amounted to as much as fourteen to eighteen hours without regular intervals for rest. The time-table of a bakery naturally depends on the importance of the batches and the materials used, on which times of the day bread is in greatest demand, and on the organisation for sale and delivery. It has to be reckoned that the preparation of a batch from the moment of putting it into the baking tins until it is fit to be handed over for consumption takes from two to four hours, varying with the process and the apparatus employed. This explains why there is no uniform arrangement. In some cases work begins at 11 p.m., in others not before 4 a.m. Some machine-bakeries have started working in shifts, and the work goes on continuously; in certain others the work begins in the middle of the night, and goes on without interruption till quite late in the morning. Some delay must be reckoned for such preparatory and supplementary operations as the rising of the dough and the stoking of the oven.

In these circumstances the baking of the bread and taking it out of the oven are not completed before the early morning. But the work is not finished then; for cakes are often baked during the morning, just when the oven is cooling; then cleaning must be done; so that work may easily last till midday.

A German enquiry of 1892 (the report of which appeared in 1893) emphasised the disadvantages of organising the work in this way, which seemed to be the average method in medium-sized bakeries of a large town. It should be added that extra hours were worked: (i) at the week-end in bakeries which did not work on Sundays, and (ii) on the day before public holidays. This same enquiry made it very clear that 46 per cent. of the bakers and pastrycooks have not in the whole year a single day of twenty-four hours free for complete rest. In numerous cases the only rest obtainable was due to the workman being out of work and the days of stoppage were so frequent that one might reckon, taking it altogether, upon a quarter or a fifth of the workers being permanently out of work (Bureau of Imperial Statistics).

According to the same enquiry the hours are even longer for apprentices. In 29.6 per cent. of the bakeries (25.9 per cent. in the big towns) the working day exceeded twelve and even eighteen hours a day. As a matter of fact the bakeries of this group had:

<table>
<thead>
<tr>
<th>Hours</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 to 14 hours</td>
<td>15.3</td>
</tr>
<tr>
<td>14 to 16 hours</td>
<td>51</td>
</tr>
<tr>
<td>16 to 18 hours</td>
<td>15</td>
</tr>
<tr>
<td>more than 18 hours</td>
<td>1.5</td>
</tr>
</tbody>
</table>

At the present time in most countries the maximum hours are fixed by law, but it sometimes happens that the regulations are not strictly observed.

The ill-effects of too long hours only begin to be apparent at the end of a few years, and are added to other causes of ill-health. It is an historical fact that a fatal case once occurred (London, 1894), viz. an English baker died after twenty-one hours of continuous work.

The third important cause of fatigue is night work, which favours the action of all adverse physiological influences.

Bakery work, except in a big business, is very often carried on at night without any shift system, and generally under unhealthy conditions. On principle there is no objection to night work with shifts that allow for alternating spells of work, if carried out under hygienic conditions, and with all possible improvements in the processes of making bread — such are found in some big concerns — but it must be realised that this improved state of affairs has not always existed, for the hours of work are decided on the one hand by technical considerations and economical reasons, and on the other hand by the demands of the public, upon which it is not necessary to insist.

The system adopted for "raising", i.e. the rising of the dough, is a very important matter from the point of view of night work; thus, for instance, there is one method, used in Scotland, which makes it impossible to bake the dough until fifteen hours after starting the preparation; but, then again, there are other processes by which the time
required for raising is reduced to ten, eight and even two hours. Direct aeration easily converts two sacks of flour into a batch of 400 loaves weighing one kilogram each ready for the oven in forty minutes.

Night work makes it possible to deliver hot bread in the morning, to have new bread in the shop all through the day and to have ready, an hour later, cakes and pastries baked after the bread. But when it is realised that the introduction, or rather the re-introduction, of night work dates in France from the reign of Louis XVI, in England from 1824, and that it has only become general in Belgium since about 1881-1882, the thought occurs that it is not quite accurate to state that it is absolutely essential to bake bread at night.

During the war for reasons of economy, and also to facilitate the distribution of food, Governments saw fit to forbid the sale of new bread, and night work was almost everywhere given up. It was started again when the restrictions were removed. Speaking generally, it might be said that in countries where night work is not prohibited, about half the bakeries have recourse to it. An enquiry by the British Board of Trade revealed the fact in 1911 that 39.9 per cent. of the bakeries began work before 4 a.m.

The German enquiry of 1892 reported the various hours at which the bakeries started as follows:

<table>
<thead>
<tr>
<th>Hours</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 8 p.m.</td>
<td>1.6</td>
</tr>
<tr>
<td>Between 8-10 p.m.</td>
<td>15.8</td>
</tr>
<tr>
<td>10 p.m.-12 midnight</td>
<td>29.1</td>
</tr>
<tr>
<td>12 midnight-2 a.m.</td>
<td>36.1</td>
</tr>
<tr>
<td>After 2 a.m.</td>
<td>21.2</td>
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</table>

Besides variation in the number of hours of work at separate bakeries, there is also often variation for the different workmen in the same bakery, so that it is very difficult to control the maximum duration of work done.

It must, however, be pointed out that in some countries the custom of working by day is kept up, notwithstanding the absence of any legislation forbidding night work (Argentina and Scotland).

The adverse physiological, ethical and social influences of night work are well known.

Night work is such that it must always be carried on under abnormal conditions, abnormal from the point of view of social as well as organic life. It favours and aggravates the condition of strain, as well as the other injurious agents. This harmful effect can be explained by the fact that the bodily system does not get sufficient rest, and that the sleep or rest taken during the day is not enough to repair the weariness due to work.

Even when it has happened that the time for rest is sufficient in duration, it is not sufficiently reparative, on account, among other reasons, of variations in neuro-humoral irritability (Blondi).

This inversion of normal life, food taken at irregular times and not wisely chosen, and also the want of the stimulating influence of daylight and lack of or insufficient sleep, rob the system of all power of escaping the condition of chronic fatigue, which slowly, but surely, takes a firm hold.

Without going into details, there is no doubt that continuous night work affects people in different ways. There are some persons who easily become accustomed to night work, perhaps because they know how to get the most out of their rest times, and these show no negative signs of ill-effects. But these are by no means the majority, and night work undoubtedly has deplorable results from ethical and social points of view; it disorganises family life, especially if the worker's wife goes out to work; it makes it very difficult for a single man to start a home; and it is an obstacle to all social activity.

Bakery work, besides, exposes workers to the action of harmful or poisonous products: dust of flour and dried yeast, which are apt to cause lesions on the skin, the teeth, the mucous membranes, the respiratory system (although, of course, this is not so serious as in the case of millers); poisonous or disagreeable gases, such as carbon monoxide from the ovens, braziers and stoves, or carbonic acid, especially in the place where the dough is left to ferment (Emmerich observed as high a percentage as 2.4 in one of these places). Cases of lead poisoning have been caused by burning in the ovens pieces of wood taken from old building materials painted with lead colours.

There is also the risk of pulmonary mycosis developing owing to mycelia, which often grow in damp and dark surroundings. These cases are often diagnosed as bronchial catarrh (Blondi).

The effect of high temperatures and stagnant air also presents an important occupational risk. The high temperatures, 38°-40° C. and even higher, compel the men to work comparatively lightly clad, and sometimes even naked. The cramped space, its unhealthy situation, often, for example, underground, and lack of ventilation add to the ill-effects of stagnant air. In summer, the factory is often heavy, damp and hot; it is difficult to avoid these conditions if the nec-
Bakery Industry and Health

Essary technical appliances have not been provided, for there is a risk of causing draughts which are unpleasant for the worker and dangerous for baking operations, e.g. for the rising of the dough.

In some countries these conditions are even worse: the workplace serves also as a dormitory for the men who sleep on the premises. It has even been reported that workers are often not provided with beds, but actually have to sleep on the shelves where the bread is placed and make their toilet in the room where they work. Even if beds are provided, the material conditions are not much better; several workers often have to share one bed.

Official and private enquiries have brought into prominence the fact that many of these premises are unsatisfactory, often dirty, and filled with all sorts of refuse; walls and partitions are seldom washed down; the sanitary conveniences are filthy, and sometimes one even finds them in a corner of the room where the work is carried on; too often lavatories are lacking altogether, and cleaning arrangements are absolutely primitive.

The bad food and irregular meals bring on diseases of the alimentary canal. These diseases of the digestion, combined with the other adverse influences referred to above, lower the general physiological state, so that there is very little resistance when the worker becomes exposed to infectious diseases.

The bad hygienic and social conditions fully explain the heavy labour turnover prevalent in this industry.

**STATISTICS**

(a) The statistics available for general sickness do not accurately represent the injury to the health of bakers caused by their occupation, for the following reasons: a considerable number of slight illnesses are not notified; serious physiological disorders generally escape the observation of those who are making enquiries, especially when the worker lives with the owner of the business; many of the harmful effects become apparent, and bring on incapacity for work, only when the worker has already adopted another trade, for the baker often leaves his trade when he feels his health is endangered.

The statistics show that the days of sickness while there is still capacity for work are more numerous than the days of sickness accompanied by incapacity. It is just the opposite of what takes place in other trades, and this explains why the rate of sickness, and also the duration of the cases of sickness, are below the average for occupations in general. This also makes it possible for experts to say that there is no question of considering that an excessive degree of sickness among bakers is definitely established as a statistical fact.

According to the Sickness Bureau at Frankfort (1900), respiratory troubles come first on the list of sicknesses which involve incapacity for work, and digestive illnesses come first amongst those not involving incapacity.

Undoubtedly the youth of the workers explains the sickness figures, for 75 per cent. of these workers are from 15 to 19 years old. In many cases children were employed (Zadek) and even women (Epstein).

(b) Enquiries and researches on the particular sickness rate of bakers show that some diseases are found much more frequently among these workers than among others.

Out of 98 bakers examined, Epstein found 52 cases of respiratory diseases, 32 of which affected the apices, 18 cases of cardiac affections, 19 cases of phlebitis, 10 cases of jaundice. After another enquiry embracing 183 sick bakers who had been treated in the Munich hospitals during 1889, the same author reported 60 cases of respiratory diseases, 54 of infectious diseases, 23 of gastro-intestinal troubles, 20 of rheumatism, etc.

Experts especially emphasise the frequency of respiratory diseases among bakers. Hirt gives 58 per cent. for all internal diseases, of which 7 are phthisical, 1.9 emphysema, 10.9 bronchial catarrh, 8.4 pneumonia.

The Berlin Local Sickness Bureau gives for the years 1889 to 1892 a relative value of 6.4 per cent. for respiratory diseases among bakers, compared with 3.8 per cent. for the total of its members, and 3.5 per cent. for acute and chronic bronchitis against 2.9 for all its members.

The Bakers' Sickness Society in Vienna points out that for 1890-1893 the average annual incapacity for work of 1,190 members was 102 caused by respiratory diseases which were classified as follows: 58 acute and chronic bronchitis, 5 emphysema, 6 pneumonia, 5 pleurisy.

According to Schuler and Zadek, pulmonary tuberculosis takes a heavy toll of bakers, and this is confirmed by numerous statistics (Epstein, Fox; statistics from Switzerland and Vienna, etc.). The older men (26-35 years) seem to show a higher percentage (57) than the younger men (24 years). This is accounted for by the fact that the frequency of tuberculosis increases with the length of employment.

Bodily deformities were also of frequent occurrence. According to the Vienna Sickness Society they figure as 22.7 per 10,000 in the case of bakers, whereas they only reach 7.1 for other trades.

For some time past the frequency of hernia among bakers has been pointed out. According to Oldenberg, it would appear that 70 per cent. of working bakers over 40 years of age suffer from this trouble, and according to the Vienna Sickness Society (1900-1907) there were 45.9 cases among 10,000 members who are...
bakers, whereas the number is only 19.9 for other associated trades.

As regards diseases of the cardio-vascular system, originally mentioned by Ramazzini, according to the numerous data collected by Layet, Spatz, Ogles, Epstein, Hoessel, Maligne, etc. according to the figures supplied by the Austrian Sickness Societies, it appears that the percentage for bakers is 3.9 and for confectioners 3.1. Of these only 1.5 represent heart disease among the former, and 1.9 among the latter group.

The reports relating to skin diseases are more important. The Munich Sickness Society in 1889 reported 49 cases of dermatitis among 175 bakers who were treated; the Frankfort Society in 1900 gave, among 905 bakers, 32 cases of dermatitis accompanied by incapacity for work and 86 cases without incapacity.

Amongst 168 bakers, of whom 18 were confectioners, Epstein reported 172 cases of dermatitis for the period 1903-1905 classified as follows: eczema 37, puritic eczema 7, various cutaneous lesions 14, itch 12, and venereal diseases 102.

Statistics on bakers' eczema (itch) deal chiefly with cases in Great Britain, where this dermatitis has been studied. At the Liverpool Charity Skin and Cancer Hospital, 197 cases were treated from 1910 to 1921; 18 cases from 1910 to 1913, 81 from 1914 to 1918, and 98 from 1919 to 1921. Parsons reported a total of 126 cases observed in different parts of England, dating from 1913, out of which 7 of the 48 cases reported at Liverpool affected master bakers.

As regards acne Galewski treated, at Dresden from 1898 to 1908, 181 bakery workers who were suffering from skin trouble, and about a third of these had acne.

The frequency of venereal diseases amongst bakery workers is explained by the conditions described above. From 1903 to 1905 Epstein observed 102 cases of venereal diseases out of 172 cases of sickness among bakers; these figures were sub-divided as follows: gonorrhoea 74, syphilis 28.

Dental lesions and diseases of the alimentary canal are also very common and take the third place in the statistics of the Munich Sickness Societies, and the first place in the Frankfort Societies. The health conditions of bakers, the direct result of the hygienic conditions under which they work, explain, according to some experts, why these workers are so seriously subject to infectious diseases.

(c) However, according to statistics, this trade has not a heavy death rate. As a matter of fact, German, Austrian, English, and Swiss statistics uniformly affirm that the death-rate is under the average in the case of young workers, and only increases in the case of those over 40. This statement has been confirmed by the work of a Commission of the British Ministry of Labour in 1919. Nelson gives the following figures for the death-rate: bakers, from 20 to 40 years old, 2.12, as against 2.31 for workers of all other occupations; bakers from 50 to 70 years old, 13.18, in contrast to 9.46 for workers of all other trades. An enquiry made by the Federation of Viennese Bakers in 1910 disclosed that the death-rate among the members of the Sickness Society for bakers was for the period 1892 to 1902, 9.7 per 1,000 and 6.4 per 1,000 among bakers and confectioners; these rates being lower than those prevailing among the members of the other federated societies.

On the other hand, Rosenfeld reported a higher death-rate among bakers under 20 years of age than among members of the same age in other federated societies. As a matter of fact, according to this expert, the Vienna Sickness Society is said to have reported in 1905 that on the one hand the death-rate per 100 members was 3.33 under 15 years, and 0.58 between 16 and 20 years, and on the other hand, per 100 bakers under 20 the death-rate was 6.28.

In the United States, according to statistics furnished by Hoffmann, and referring to 1,307 deaths among bakers, the death-rate due to respiratory diseases is 34 per cent., including 20.4 due to tuberculosis. The statistics for deaths in 1909 show a total of 952 for bakers and these are divided up as follows: out of every 100 deaths for the group aged from 25 to 34 years, pulmonary tuberculosis 29.1, pneumonia* 12.1, chronic nephritis 2.8, suicide 5.7, accidents 12.8; for the group aged from 35 to 44 years, deaths due to the same causes were respectively *99.9, 7.4, *3.9, *4.5, 5.7; for the group aged from 45 to 54 years, **15.7, 8.9, *9.8, *4.3, 5.6. In this last group the figures for cancer are 9.6, and diseases of the heart 9.6. [The figures which are marked with an asterisk (*) show a higher percentage than those referring to all occupations. It must, however, be noted that this latter group includes 210,507 deaths, whereas the group of bakers only contains 952 deaths, including 141 at ages 25 to 34 years, 176 at ages 35 to 44 years, and 198 at ages 45 to 54 years.]

According to the statistics, the highest death-rate is due to respiratory diseases and the next highest to diseases of the heart. According to Bertillon's early statistics, the death-rate used to be higher for all ages in the big towns. Most experts draw attention to the existence of a high death-rate from respiratory diseases in the bakery trade, which is considered a definitely established statistical fact.

A recent enquiry carried out at Nancy (1925) shows a death-rate of 10 per 1,000 due to tuberculosis among working bakers, whereas for the whole population of the city it was only 2.5. A comparison with the number of confectioners shows that confectioners have a lower death from tuberculosis than bakers. The morbidity in the bakery trade is nil and the morbidity below 1 per cent. This difference is due to the fact that bakers work longer hours and to the fact that working bakers do not benefit by the eight-hour law, nor do they get a weekly rest.
In Italy an enquiry was effected in 1925 in regard to hygiene in bakeries. It was carried out by public health authorities under the control of provisional health officers. It was also intended to effect an investigation into health conditions, but the data on the incidence of dermatitis, eye disease, respiratory troubles, etc., were not considered to be sufficiently exact to warrant being made the subject of a statistical enquiry.

This enquiry revealed the fact that through the baking industry has, especially in certain districts, made great progress, it has not as a whole attained a satisfactory level of technical perfection. The industry comprises even at the present time too many family businesses, with the result that, especially in Southern Italy, the hygienic conditions are below the average.

The 29,067 bakeries inspected employed about 60,196 workers (12,684 women, 21.1 per cent., and 2,614 children, 4.4 per cent.): approximately 21,000 of these workers were about 80,196 workers (12,684 women, 21.1 per cent., and 2,614 children, 4.4 per cent.).

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Some 3.7 per cent. of these bakeries were found to have unsatisfactory lighting and 3.5 per cent.

On the other hand, cleanliness left much to be desired in the case of 34.7 per cent., 32.8 per cent. were without sanitary conveniences (17,351 workers, 28.8 per cent.), 67.2 per cent. were without washing accommodation (51,825 workers, 85.1 per cent.), 88.5 per cent. without cloakroom accommodation (50,105 workers, 83.2 per cent.); in 25.8 per cent. no working clothes were provided; if 2.1 per cent. of the bakeries the workers slept in the bakery itself.

PATHOLOGY

Diseases of the locomotor system are represented by muscular and articular rheumatism due chiefly to chills supervening on a state of exhaustion; by troubles connected with the growth of bones, which is an indication of strain in the case of young workmen, but which are often found in the case of adult workers also; by flatfoot, also due to fatigue of the posterior tibial muscles and to relaxed ligaments of the plantar arch caused by standing for long hours.

The most characteristic lesions were deformities of the legs, and the most frequent was certainly *Genu valgum* — the knock-knee of the baker. In the case of this lesion, which is all the more easily developed because bony growth is not completed in the case of young workers, the leg forms with the thigh an angle opening outwards; there is contraction of the adductors of the thigh with hyperextension and external rotation. The lesion is sometimes uni- and sometimes bi-lateral; it is chiefly observed among workers who formerly suffered from rickets, or who suffer from a delayed form of the disease.

The lesion is due to the fact that the worker chooses a position which, while it tires the muscles less, involves pathological modifications of the bones. When only one leg is affected by *Genu valgum*, or if the condition is uneven and especially noticeable on one side, shortness of the affected leg develops with lowering of the pelvis and a pathological curvature of the vertebral column.

*Genu varum* — that is to say, bow legs, concave inwards, with contraction of the adductors — used to be, and still is, much rarer.

These two lesions reappeared during the war among young bakers who had been rejected by the military doctors. These young men provided extremely favourable ground for the development of these lesions, for apart from their physical weakness and their disposition to rickets, they were the victims of bad environment and insufficient feeding. The long hours of standing and the loss of elasticity of the vascular walls bring on, in the case of old bakers, trouble in the venous circulation of the legs, with varicose veins, swollen feet, thrombosis, phlebitis, and abscess in the leg.

Physical degeneration, the result of the work, explains why the apprentice bakers appear lowest on the list, from the military point of view, as regards size and weight.

Cardio-vascular lesions affect the kneaders chiefly (Shann, Hallfort) and the men who carry the bread (Zadek) — these latter are especially susceptible owing to their youth. The lesions consist essentially of hypertrophy of the heart, acute or chronic dilatation, and valvular lesions.

As regards vaso-motor disturbances, congestion of the head, epistaxis and erythema are reported.

Strain and overwork are not alone responsible in the etiology of the cardio-vascular lesions, for an important part is also played by anaemia, brought on by bad ventilation, etc. Nervous troubles take the form of neurasthenia, which often shows itself in a sexual form and this is encouraged by the promiscuity referred to above; 4 cases were observed by Kopp in 1903-1905 among 168 bakers suffering from various affections.

Suicides occur frequently. The regular statistics published in Great Britain for 100 trades prove that the bakery and pastrycooks rank third among the trades where suicides are most frequent.
The most important injuries caused by the various forms of dust are itch or baker's eczema, described for the first time (in 1817) by Willan under the name of "diffuse psoriasis".

This disease starts with a sensation of burning on the anterior and cubital surfaces of the forearms, as well as on the back of the hand, associated with some degree of pruritus. When the disease takes an acute form, a little papular vesicular eruption appears, becomes vesicular, opens and begins to weep. Itching is pronounced and becomes exasperating when the arms are exposed to heat.

The chronic form the skin is infiltrated and hard, with tags and dry scaly patches more or less circular in shape; sometimes the patches weep (the moist kind).

Baker's eczema is protein and the various states of its evolution — papular, vesicular, and pustules — are often associated with each other. The lesion is generally bilateral, but often spreads, through scratching and auto-inoculation, on to the face, the genitals, and even, in bad cases, all over the body. This eczema is often infected in a secondary way, forming pustules at some depth.

According to recent reports there does not seem to be any seasonal distribution; in some cases it is very hard to cure this dermatitis, especially in the case of elderly persons.

The etiology of baker's eczema has been discussed a good deal. According to Prosser White, a very important point is to distinguish and to exclude occupational diseases from the two following pathological conditions: seborrhoeic, eczematous, lichenoid, psoriasis-like, and the erosive, papuloid or pustulous. Blame attaches to the flour, the dust of which mechanically obstructs and irritates the skin. Different qualities of flour vary in their irritant capacity: a good quality of flour does not cause dermatitis, which, for example, is not found in biscuit factories where a superior quality of flour is used. Chemical products mixed with the flour are also blamed, such as persulphates or nitrates of calcium, or acid phosphate of lime; or again those chemicals used for whitening flour, e.g. chloride of lime and peroxide of hydrogen. Yeast, sugar and salt have also been blamed. De Jong has attributed the dermatitis to some peculiar property belonging to salt, and supported his hypothesis by the fact that the same lesions are found among salters and packers of herrings and packers of rock salt. The salt which is contained in the dough, and which impregnates the arms of the worker, crystallises when he approaches the oven.

Other agents appear to be responsible for baker's itch: exposure of bare parts of the body to heat; maceration of the skin by sweat, and by kneading the dough (as a matter of fact dermatitis is most often found among the staff of bakeries where the dough is prepared or kneaded by hand); water used for washing the hands; individual negligence and lack of cleanliness. Then again the blame is put on the action of ordinary parasites — encouraged by sleeping together in bed, and by lack of cleanliness — and on the specific parasites of flour (acari) or on the inferior qualities of the sugar sometimes used for adulterating the flour. McCormick, of Liverpool, considers that 55 to 65 per cent. of the 180 cases of itch he observed between 1914 and 1921 were due to an acarus.

Undoubtedly individual predisposition must be taken into account, whether local or general, and particularly the condition of anaphylaxis (sensitivity to proteins) of each individual.

On the other hand, lack of cleanliness, and numerous little cracks in the skin encourage the formation of boils, whillos, etc., and are liable to bring on inflammation of the subcutaneous cellular tissues (phlegmons, abscesses, etc.) and even of the lymphatic system.

It must be realised that cases of itch may be met with among bakers, and that, by the act of scratching, this may pass on to eczema, and it is really very difficult to distinguish whether it is eczema or a recurrence of the itch. Besides there may actually be seen, in the same person, baker's eczema, itch, and eczema secondary to the itch.

Dental lesions are very important and are characterised by a soft progressive form of decay, which starts in the neck of the tooth, and spreads over the surface towards the crown (superficial caries). The front teeth are affected first; they are naturally the most exposed to whatever causes the lesion, and turn brownish or blackish. In the case of young men, other lesions are observed, due to the flour dust forming a kind of mastic which impedes the growth of the teeth.

The pathology of these lesions is rather complicated. The dust which comes from flour, and especially that which comes from sugar deposited on the free surface of the teeth, becomes transformed into saccharic, acetic and oxalic acids, etc., encouraged by the constant presence of bacteria in the
temperatures, causes, typical and can be explained by other points out, but these changes are not diminished in haemoglobin has been living and feeding, and to dental caries. A diminution in haemoglobin has been chiefly due to the irregular condition of the carrier finds conditions favourable to persistent effect, but the hygienic condition of flour dust does not seem to.

Cases of gastroalgia and gastritis are mostly reported, generally than the acute form, which is common than the chronic forms are reported, generally as a matter of fact, this form of caries is most often found among pastrycook confectioners, who handle sugar most of the time, rather than among the bakers who work mostly with flour.

The action of acids is to decalcify the tooth; the phosphates and carbonates of lime in the enamel and the bone become dissolved; then, when the decalcification has taken place, the bacillus of putrefaction enters the stage and plays its part. Of course this process of destruction is favoured by predisposing conditions, such as bad feeding and lack of attention to the teeth.

Lesions of the mucous membranes are due to dust caused by flour and sugar, etc., which combine with the secretions to form a sticky, irritating mass. But there are quite a number of experts who deny this irritating action of flour and attribute more importance to the high temperatures, which parch the mucous membranes, and to chills. Whatever may be their cause, these lesions are specific by their etiology, but not by their symptomatology.

Amongst forms of sickness may be quoted blepharitis, conjunctivitis, and external otitis. Among the more important forms must be noted lesions of the respiratory passages. As regards the nose and pharynx, chronic forms are reported, generally accompanied by swelling and redness of the interarytenoid region, and lesions of the vocal chords. Chronic bronchitis, which may extend to the furthest branches of the respiratory tree, is more common than the acute form, which is peculiar to beginners. Of all lesions, chronic bronchitis is the worst. It is due to the inhalation of large quantities of flour dust.

Narrowing of the small bronchial tubes brings on capillary bronchitis accompanied by cough, glairy expectoration, atelectasis of the corresponding pulmonary alveoli and emphysema with dyspnoea (asthma). These lesions, in their turn, bring on circulatory troubles sometimes ending in complete cardiac insufficiency. The inhalation of flour dust does not seem to have a persistent effect, but the hygienic conditions are such that any bacillary carrier finds conditions favourable to the diffusion of disease by spitting. Cases of gastralgia and gastritis are chiefly due to the irregular condition of living and feeding, and to dental caries. A diminution in haemoglobin has been pointed out, but these changes are not typical and can be explained by other causes, such as the effect of high temperatures, of poisonous gases, carbon monoxide, lack of sunlight, bad hygienic conditions, long hours spent in badly ventilated, and badly lighted premises, and fatigue.

The high temperatures also cause congestions, epistaxis, and erythema of the exposed part of the body.

Rheumatic troubles arise from sudden changes of temperature, and from draughts. It must also be noted that bakers are exposed to many accidents arising from defective lighting of underground premises and stairs; from active work carried on at night and, sometimes, when the man is half asleep; and from machinery, such as doughmixers, dialers, kneaders, and cutters. These accidents take the form of burns, fractures, and cuts.

HYGIENE

Prophylactic measures consist essentially in general hygienic measures, either in relation to the premises where the work is carried on, or to the baker himself, or even to the organisation of the trade.

Among the chief hygienic improvements of the premises, the first to be urged should be abolition, if possible, of underground bakehouses, better conditions of natural or artificial lighting, of ventilation and of cleanliness.

The question of ventilation is no doubt difficult, for it involves problems of heat, of smoke production, and the constant condensation of moisture; but the difficulties are not beyond the capacity of modern technique. Arrangements should also be provided for freshening the air, which ought not to be too dry.

The working premises should be kept scrupulously clean. Regular cleaning down with water of the floors of rooms where kneading is done, and of ovens is recommended, and also scrupulous cleanliness of all receptacles used for preparing and making dough and bread, including machines, tins, and baskets. No one should be allowed to sleep in the rooms where the kneading is done.

As regards personal hygiene the worker should be admonished to safeguard his health by paying scrupulous attention to cleanliness; this will, however, only be possible where adequate material facilities are available for his use. Lavatories must therefore be provided and kept in working order in a part of the building quite separate from the rooms where the breadmaking goes on. These lavatories
must be up to hygienic standard (see article “Personal Hygiene”) and must be provided with the necessary means for cleansing the mouth and nails, for this is essential if eczema and dental caries are to be successfully avoided.

Arrangements must also be made for the provision of douche baths, drinking water, dressing rooms, and canteens. Where the workers are housed by the owner of the bakery, the sleeping accommodation must conform to hygienic requirements (see article “Social Welfare”).

Among the measures of personal hygiene must be included the practice of medical examination on commencing work and also periodically.

An adequate working organisation should make use of all practical means for improving the hygienic and sanitary conditions of the trade. First and foremost hand work should be superseded by mechanical means, by mixers, kneaders, and machines for cutting up and shaping; this step is not only a means of prophylaxis against fatigue, but it also prevents the diffusion of flour dust. Most machines are closed in, and can be adapted in such a way that no dust is liberated either from the flour or from dried particles of dough.

Then the hours of work must be limited, and night work must be stopped in the baking trade as at present generally carried on. Yet as regards big establishments where work goes on continuously, and is executed in three shifts, and which, as a matter of fact, are very well equipped from both technical and health points of view, the drawbacks of long hours and night work completely vanish; the workers are not overstrained and night work can be taken in alternate spells.

**LEGISLATION**

The work of women and children is regulated either by general laws or by special laws to be dealt with further on.

In addition to general regulations on the hygienic conditions of the workplaces, special regulations on bakeries have been laid down in the following countries:

**Austria**: Ordinance of 1893 of the Magistrate of Vienna and the Austrian Act of 3 August 1919 on children in bakeries.  
**Belgium**: Royal Decree of 22 July 1925 laying down proper measures to ensure the hygiene, health and safety of bakers and bakery workers.  
**Finland**: The Regulation of bakeries of 16 July 1908.  
**France**: The Decree of 26 August 1923 laying down the ban on night work.  
**Germany**: The Prussian Ordinance of 1911 relating to children and adolescents. Act No. 71 of 31 March 1926, modifying the Act of 9 June 1920 on sleeping accommodation of the personnel.  
**Great Britain**: Section 27 of the Factory Act of 1901 and the Order of 30 December 1902 on the minimum cubic space. The Act of 1920 regarding women and children. Welfare Order of 26 February 1927 for factories and shops where bread, pastries and biscuits are prepared.  
**Norway**: The Royal Decree of 26 August 1916, etc.  
**United States**: Indiana Act, 1919; Massachusetts Act, 1921; etc.

These laws or regulations lay down measures which are more or less detailed, as to the depth, height and cubic capacity of the workshops, the cleaning or white-washing of walls, lighting, ventilation, removal of waste water, the provision of drinking water, sanitary conveniences and lavatories; prohibition of the use of underground work places which do not meet the minimum of hygienic requirements; the prohibition of the use as sleeping quarters of places annexed to bakeries and not completely separated from them.

Medical examination on commencing work, and periodically, is quite frequently laid down.

The question of the hours of work is intimately bound up with that of the prohibition of night work.

Acts restricting the duration of work have been passed by Austria (1912, 1919, 1920), Belgium (1921), Czechoslovakia (1919), Denmark (1921), Italy (1898), Germany (1896-1923), Netherlands (1919, 1920, 1922, see section 4, Article 33 and following, 1923), Poland (1921), Sweden (1920-1923), etc.

For a long time the problem of prohibiting night work has been the subject of discussions at hygienic and sociological congresses, as well as of demands from the workers.

Night work is actually (1926) prohibited by law in a large number of countries (about 23). Various enactments differ in their details as to the compulsory period for rest (generally from six to nine hours), as well as with regard to exemptions. Various exemptions deal with certain kinds of work or certain kinds of bakeries, and temporary ones deal with unforeseen circumstances, such as accidents, and matters beyond control or with foreseen overtime at holiday seasons. The text of these exemptions is sometimes loose, sometimes rigid. Amongst others may be mentioned the Austrian Act of 3 April 1919; the Belgian Act of 14 June 1921 on the eight-hour day, and the Royal Decree of 10 August 1924 relat-
ing to the length of the working day in the baking trade; the 
Chilean law of 31 December 1924, and of 24 February 1925; the 
Czechoslovakian Act of 19 December 1918; the Danish law of 
9 June 1920; the law of Finland of 4 June 1908; the 
French Act of 23 March 1919; the German Ordinance of 23 November 1918; the Greek 
Ordinance of 14-27 September 1912, modified by the Royal Ordinances of 24 December 1921; the Italian 
Ordinance of 22 March 1908; the Latvian Act of 
11 March 1923; the Norwegian Act of 
14 April 1906 and the provisional Act of 
4 June 1918 (length of rest to be twelve hours); the Act of New South Wales of 
23 December 1919; the Dutch Act of 1 Nov-
ember 1919, modified by the Acts of 1921, 
1922, and 1923 (length of rest to be ten 
hours); the Polish Act of 18 December 1919 
and the Ministerial Decree of 10 Decem-
ber 1923; the Decree of the Central All-
Russian Council of Soviets of 29 November 
1921, and the Decrees of the Commis-
sariat of Labour of 24 August 1922 and of 
10 March 1923; the Spanish Decree of 
3 April 1919, and the Ministerial Decree of 
10 June 1919; the Swedish Act of 
22 June 1923 (length of rest: 10 hours); the 
Cantonal Acts of the Swiss Confederation; the Act of Uruguay of 
19 March 1908 and of 15 October 1920; etc.

From the international point of view it should be mentioned that at the Session of the 
International Labour Conference in 1925 a Draft Convention concerning the 
prohibition of night work in bakeries was adopted. The Draft Convention prohibits 
the making, during the night, of bread, 
pastries, or similar products with a flour 
basis, but does not apply to the wholesale 
manufacture of biscuits. The prohibition ap-
plies to the work of all persons, masters 
and workmen alike, with the exception of 
domestic manufacture on the same family.

The period of rest laid down is at least seven hours and includes the interval be-
tween 11 p.m. and 5 a.m. (10 p.m. to 4 a.m. 
under certain conditions).

Permanent exemptions deal with the 
carrying on of preparatory and supple-
mentary work which may not be done by 
young men below 18 years, with bakeries 
in tropical countries, and the weekly rest.

Temporary restrictions relate to over-
time, to emergencies of an ordinary kind, 
to accidents and circumstances beyond 
control.

Compensation for occupational diseases 
of bakers is provided by Great Britain, 
where baker's itch is included under the 
heading of dermatitis produced by dust 
or liquids, and by Queensland for phthisis 
among bakers.

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Barium (Compounds of)

French: Barium (Compôsés du). — Ger-
man: Bariumverbindungen. — Italian: 
Composti di bario. — Spanish: Com-
puestos de bario.

CHEMICAL PROPERTIES

Metallic barium (symbol Ba; atomic 
weight, 137) is a metal which alters very 
easily on exposure to air and which is 
not applied industrially. Amongst its 
compounds the following should be noted:

(1) Sulphate of baryta (barite, heavy 
spar, or fluo spar) (French: Sulfate de 
barium, baryline, spath pesant, or spalt: 
German: Bariumsulfat oder Schwefelhydrat 
Barium; Italian and Spanish: Solfato di 
bario) (formula, Ba SO₄), a white solid 
insoluble substance very dense (4.5) and 
widely distributed in nature in the form 
of elongated strata. All other compounds 
of barium are usually prepared from 
barytes passing through the sulphide. 
There is found on the market the natural 
sulphate and the sulphate prepared arti-
ficially. The bits of barytes extracted 
from the mine are washed, dried, crushed, 
and very finely powdered. The paste is 
sometimes made with water. Artificial 
sulphate is obtained as a by-product in 
the manufacture of hydrogen peroxide.

Large quantities of sulphate of barium 
are also manufactured as the chief pro-
duct by precipitating solutions of barium 
chloride by means of sulphuric acid or 
magnesium or sodium sulphate. Like the 
chloride (see later) it is prepared by 
starting with barytes; this method of 
manufacture is in fact a process of purifi-
cation of the natural sulphate. 

The barium sulphate is found on the 
market under the name of "fixed white " 
(blanc fixe), a paste with 15-20 per cent. of 
water. Its fine white colour, quite unalter-
able, causes it to be used in painting, but since its covering power is poor it is mostly used mixed with other pigments or colours: white lead, Venetian white, Hamburg white, Dutch white (see article "White Lead"), chrome green, Prussian blue, etc. It is very largely used for imparting a satin sheen to papers (wall paper, decorative paper, photographic printing papers), in the manufacture of lakes made from tar colours, of artificial ivory, of rubber goods, etc. Gorgonzola cheeses are sometimes covered with a crust of barium sulphate.

(2) Lithopone, a mixture of zinc sulphide and barium sulphate (see article "Lithopone").

(3) Barium carbonate (French: Carbonate de baryum; German: Bariumkarbonat, Kohlensaures Barium; Italian and Spanish: Carbonato di bario) (formula, BaCO₃), a solid white salt, very slightly soluble in water, and which only decomposes at a very high temperature. It is found in the ground (witherite) in Great Britain, Silesia, Hungary, Syria, Russia, South America, etc.

The industrial preparation consists in heating a mixture of heavy spar, coal, and carbonate of potassium or "pearl ashes". Potassium sulphide and carbonate of barium are formed and separated by washing in water. This process also facilitates the preparation of other barium derivatives.

(4) Barium sulphide (formula, BaS), obtained by reducing the natural barytes by coal and draffing it with water. Substances facilitating reduction are often added to the mixture of barytes and coal — such as resins, oils, bitumen, sawdust, sea salt, etc. Barium sulphide is very alkaline and serves as the starting point in the manufacture of most of the barytic compounds: Caustic baryta (Ba(OH)₂), which presents the same properties as the caustic alkalis (see also article "Lithopone").

(5) Barium chloride (BaCl₂), a crystallised substance, soluble in water, used in laboratories as a reagent of sulphuric acid and of sulphates and for preparing and fixing white. Barium chloride is obtained by heating in a reverberatory furnace heavy spar mixed with limestone and calcium chloride.

(6) Barium nitrate (Ba(NO₃)₂), a colourless crystalline substance, prepared from barium sulphate, is used in pyrotechnics for preparing green fireworks.

**Toxic Action**

The metal presents no danger. The compounds equally would not seem to be of great importance from the point of view of industrial hygiene, yet when absorbed in strong doses by way of the mouth they may give rise to serious poisoning (Lehmann). In theory the occurrence of acute and chronic poison-
He found amongst these workers caustication of the conjunctivae and of the cornea differing from ordinary caustication by certain characteristics typical of the evolution of the lesion.

Sequira states that workers using salts of barium in the manufacture of fireworks have their hair whitened, and fairly often lose their hair and their eyebrows.

Whilst the neutral salts only exert a local action, the soluble salts are said to be absorbed and to give rise to a general action on the circulatory system (heart and blood vessels), digestive system, central nervous system, as well as the muscles. Elimination is by way of the salivary glands, the intestines, and in small quantities by the urine. Certain substances likely to liberate oxygen when mixed with inflammable or oxidisable substances, whilst free from danger when isolated, demand many precautions in course of transport. Thus, for instance, the presence of bioxide of barium in a cargo caused a fire on board ship. It is for this reason that adequate measures are required if accidents of this kind are to be avoided (B. Müller).

STATISTICS

Besides the cases reported above, it is known that four cases of poisoning by sulphuretted hydrogen were notified in Austria in a chemical undertaking, where barium carbonate was prepared by causing natural carbonic anhydride to pass through a solution of barium sulphide contained in large saturation vats. Two cases of serious poisoning by the same gas were reported (1908) in an establishment where barium chloride was prepared. One of the workers remained unconscious for two days.

The 1905 report of the German Trade Association for the Chemical Industry similarly cites a case of poisoning by barium chloride. Kipper noted (1926) a case of poisoning affecting a worker who had been employed for a few days on grinding barium peroxide. He suffered from paralysis of the right arm and leg, acceleration of cardiac activity, cyanosis of the skin, he complained of gastric pain and vomiting. Death supervened at the end of three days. The dust raised in course of the occupation was very abundant and contained 14 per cent. of barium oxide and 30 per cent. of carbonate (both highly soluble in the system).

HYGIENE

In salts of barium factories, where the product is got by reducing barium sulphate, adequate measures should be taken to render the flooring impermeable and for ensuring thorough ventilation of the workrooms.

Construction and maintenance of the furnaces should be so organised as to prevent all danger from radiant heat and all risk of fire for the workers as well as for the neighbourhood (exclusion of combustible material from proximity to the furnaces).

Measures of protection should be taken against liberation of sulphuric gas and other injuries, and against disagreeable fumes, in workrooms and in the surrounding atmosphere. Catching and evacuation of dust is also called for.

Condensation of nitrous fumes must be effected when nitrate is decomposed for the preparation of caustic baryta. Vats and baths in which treatment is effected (decolorising of sulphate of baryta by means of hydrochloric acid in open vessels) should be provided with covers and the gas directed in to a very high evacuation chimney with a very strong draught. When stoves are used for drying the sulphate they should be constructed of incom bustible material; washing water should be neutralised with lime or carbonate of lime before being cast into sewers.

Preventive measures should be taken to avoid risk of contamination of the subsoil and of water, either by raw materials or by the products and their residues especially on account of the toxic properties of salts of barium.

Workers should receive protection during manipulation of acids and also against risk of poisoning.

Measures of personal cleanliness should also be enforced.

LEGISLATION

In Italy, boys under fifteen and women under twenty-one are excluded from salts of barium factories; they are also excluded from baryta factories when dust is liberated freely in the workrooms. Barium and its salts are not included in any schedule for purposes of compensation.

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Bark


Bark is the external covering of the trunk and branches of trees. The bark of trees generally varies greatly as to thickness, being sometimes 4 cm. thick, but
often much thicker. Types of bark used in industry are:

1. Bark for tanning. This kind of bark is obtained from numerous common native and also exotic and tropical trees. The kinds used are very numerous and contain, according to the type, from 4 to 30 per cent. of tannin. Without giving a complete list, the following kinds of bark may be mentioned: alder, birch, chestnut, oak, beech, pine, willow, aspen, etc. There are, however, a very great number of trees in addition to these which contain to a greater or lesser extent astringent matter. The kind of tannin contained in the different plants varies.

2. Bark for dyeing. This kind of bark is becoming less frequently employed, being increasingly replaced by artificial dyeing substances. Amongst others are used prickly-ash (bright yellow), chestnut (grey and black), pomegranate (grey), buckthorn (green), quercitrin oak (yellow), brown and red.

3. Pharmaceutical bark used for tonics and febrifuges; carcarilla, cinchona, willow, imitation angustura, monesia, antihelminthics, rhatany; bark applied for other purposes: spurge flax bark, etc.

4. Bark for domestic use, such as Panama bark, which contains saponin, enabling it to replace soap when boiled, in making whisky, brewing, soaps, and other purposes. spurge flax bark, etc.

5. Cork bark (see article "Cork").

6. Bark used in the manufacture of fancy goods and wooden goods (frames, mouldings, etc.). Wild cherry bark and birch bark (the bark of the black birch), for instance, are notably used for the manufacture of light watertight craft.

**INDUSTRIAL PROCESSES**

Stripping, the object of which is to separate the bark from the wood in more or less extensive sheets, is generally effected in spring while the sap is rising. It is done by hand by tracing in the lower or upper or both extremities of the trunk a circular incision penetrating to the sap wood, then vertical incisions all round the trunk. With a curved tool in wood or iron the bark is detached in strips following the incisions. Barking may be carried out by a more effective method by injecting steam between the bark and the wood (Maitre, Nomaison, Vacheron processes, etc.), the latter possessing the further advantage of permitting stripping of bark at all seasons.

For the manufacture of tan, the bark is reduced to powder in a drum provided with knives and thereafter put into a ball mill or ground under pestles. Often tanners prepare the bark themselves.

For the manufacture of objects in moulded wood made from bark, the bark is stamped by pressure in moulds.

**SOURCES OF INJURY**

(See article “Plants”.)

**HYGIENE**

Reference should be made to the abovementioned article. It must, however, be stated that bark mills situated in towns come within the category of scheduled establishments and are thus obliged to enforce certain hygienic provisions. In this manner, workshops must always be well ventilated and provided with exhaust installation for removal of the dust liberated. Apertures giving on to public highways or neighbouring properties must be closed or protected with sheet metal. Pestles and mills must not be situated near common walls and must be so installed that neighbours are not disturbed by the noise made. The emplacement of the power machine must be separated from the workshops and stores, etc.

In France young persons under 18 are excluded from bark mills in towns when dust is freely liberated in the workshop. In Spain boys under 16 and women under 21 are excluded from grinding rooms in bark factories.

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**Basic Slag**


**TECHNICAL DATA**

Progress in industrial technique led to the discovery that the manufacture of cast steel and iron ("homogeneous iron") by the Bessemer process gave cast metal rich in phosphorus which did not lend itself well to decarbonisation, and produced a defective and useless iron because the phosphorus did not burn and remained in the iron instead of passing into the slag.

Thomas and Gilchrist demonstrated in 1878 that this disadvantage was due to the presence of a considerable quantity of silicic acid in the interior linings of the converters, which had the effect of rendering the metallic bath and preventing the transformation or separation of the phosphorus in the slag to the state of calcium phosphate. The acid phosphates or phosphoric acid resulting therefrom
became reduced by the iron, and the latter always contained phosphorus.

These experts then proposed to replace the acid lining of the converters by a basic coating formed of pulverised magnesia and dolomite mixed in a paste with a little tar and compressed, and to add eventually to each charge some quicklime (10 to 15 per cent.) and a covering flux.

The slag thus contains all the phosphorus, which separates out in the form of calcium phosphate. Dephosphorisation takes place in four or five minutes, and the slag is discharged by inclining the converter at a suitable angle. It may be staved roughly that for each ton of steel there is obtained two to three hundred kilograms of slag, which float on the top of the molten steel in the furnace and which may easily be removed from the surface by means of an iron tool. The slag thereafter takes the form of a hard spongy mass, which is pulversised in half an hour.

At present phosphorated slag is also obtained in the Martin steel process. It can be rendered more friable by making it flow, still in a molten state, into water.

The slag extracted from the converters and cooled is generally stored for a more or less lengthy period. It is then sorted by hand to remove the pieces of iron which it may contain, and thereafter passed to extractors (electro-magnetic) which retain the iron or steel contained therein.

The slag is then submitted to crushing, with a view to reducing it to pieces of the size of a nut, and thereafter to a series of grinding and sieving operations, rendering it more and more fine with a view to obtaining finally a powder of the requisite quality.

The slag is transported mechanically to storing silos, to an automatic bagging apparatus, or to a wagon-loading centre.

The modern Mathesius process does away with the operations of crushing and grinding by submitting the crude slag for two or three hours to a pressure of ten to twelve atmospheres in a steam boiler, which has the effect of reducing it to dust.

For the preparation of "silicate of cotton" or "mineral cotton", a jet of molten slag is violently pulversised by being brought into contact with a jet of steam. The sudden cooling gives rise to the formation of small particles of slag in the form of filaments similar to cotton threads, which fall on the floor of the pulversisation room like threads of wool or spun glass.

The Thomas slag has a colour which varies from reddish brown to nut yellow. It contains phosphoric acid (14 to 20 per cent.), probably in the state of tri-calcic basic phosphate combined with a molecule of calcium. It also contains free lime (10 to 20 per cent.), silica, oxide of iron, manganese and magnesium, etc.

Thomas slag is put on the market in the form of a very fine powder, since its efficiency as a manure is proportionate to the fineness of the powder.

**USES**

Having remained for long without being utilised industrially, Thomas slag is to-day becoming more and more generally employed as an artificial manure, after reduction to a fine powder. It is also used in the manufacture of "silicate of cotton", which serves as a heat-insulating material or for deadening sound (for walls and floors, etc.).

**SOURCES OF DANGER**

It is sufficient to note the risk of burns in the course of manipulating Thomas slag while still hot.

Granulation of the slag in a jet of water prevents, it is true, the liberation of dust, but gives rise to the production of sulphuretted hydrogen. The principal risk, however, is that caused by dust liberated in a state of very fine subdivision. The discharging of slag is particularly harmful, since this operation is excessively dusty, especially when it is a question of slag which has been stored for a long time and which has started to disintegrate as a result of the influence of carbon dioxide and atmospheric humidity. Crushing, grinding, and passing through sieves also gives off a considerable quantity of dust due to lack of airtightness in the apparatus in which these operations are effected or in the localised exhaust devices with which they are furnished.

Bagging is a very dusty operation despite the precautions taken (automatic apparatus with localised exhaust), since the dust has a tendency to pass through the material of which the sacks are made and to fall on the ground when the sacks are moved, with a result that the floor of the workroom becomes covered with a layer of dust which is continually raised by the feet of the workers or by the wheels of vehicles.

The storing of sacks may itself be a source of danger. Some sacks burst under the pressure of those placed on top of them, but chiefly because the powdered slag attacks the material of which they are made. As a protection against this, resort has been made to a system of storing the powdered Thomas slag in wooden silos, only filling the sacks as required.

Beating emptied sacks which have contained Thomas slag is a dangerous operation on account of the dust liberated. This is also carried out in closed receptacles, which is all the more necessary since it is essential to avoid exposing the workers occupied in repairing
the sacks to the harmful action of the dust.

The transport of Thomas slag is also a source of danger for workers in the transport industry (dockers, railwaymen), who have complained of the harmful effects of this product. Dust, in fact, may pass through the sacking even when it is of very close texture.

In the course of manufacture of silicate of cotton, risk is connected with the action of small particles of this product, especially at the moment of packing.

Finally, agricultural labourers engaged in spreading the slag over the fields are exposed to the same dangers as the workers. The danger in question is specially serious when gusts of wind raise the fine slag dust in the atmosphere, thus facilitating its entry into the eyes and respiratory passages, etc.

**Harmful Effects**

According to certain authorities, Thomas slag is said to possess mechanical action, the reason for which is to be found in the very sharp cutting points of the small, hard grains of which the dust is composed. Other authorities hold that it is chiefly a question of chemical action due to the presence in the dust of particles of free quicklime, phosphorous compounds, sulphuric acid, etc. This hypothesis would seem to be confirmed by the fact that different varieties of slag are more or less harmful without microscopic examination being able to explain such variations for physical reasons. As regards lime, Roth draws attention to the fact that it cannot be an exclusive cause of injury, since slag, after long storing involving the transformation of all the free lime into carbonate of lime, still remains harmful. Further, no lesions analogous to those found among workers on Thomas slag are noted amongst limeburners.

As regards phosphoric acid, the opinion is held that this product in combination with quicklime in the form of tetra-phosphate is neither corrosive nor harmful.

It is, moreover, more highly probable that the harmfulness of slag is due at once to a physical and a chemical action (Villaret, Rambousek, Koelsch).

**Statistics**

The available statistics affect chiefly workers engaged in Germany on the grinding of Thomas slag.

A very detailed enquiry dealing with almost all the slag mills was carried out several years ago by the Health Office of the Reich. It reveals the high incidence among the workers of respiratory diseases of serious development.

Statistical returns prepared by Weyl and dealing with three establishments employing 9,994 workers (or an annual average of 998) over a period of ten years (1903-1913) gave the following figures relative to 100 workers:

<table>
<thead>
<tr>
<th>Total number of diseases</th>
<th>Duration of each case of illness</th>
<th>Total number of respiratory diseases</th>
<th>Duration of each case of respiratory disease</th>
<th>Cases of death by pneumonia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases</td>
<td>Days</td>
<td>Cases</td>
<td>Days</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>100</td>
<td>1,157.9</td>
<td>41.5</td>
<td>505.8</td>
</tr>
</tbody>
</table>

These statistics prove that sickness rates have been very high, as is seen when it is taken into account that for the same number of workers normal morbidity figures (number of cases) are from 40 to 43 cases per annum (statistics taken from the Reich insurance returns) and that the normal gravity of illness (duration of illness) is 850 days per annum. It is therefore seen that in the instance under consideration morbidity is twice as high and twice as serious.

The state of health of the workers in the Thomas slag industry is all the more striking when compared with that of the other categories of workers or social grades contained in the table on page 221.

In 1926, five factories with 633 workers showed per 100 workers: 88.9 cases of sickness, 28.1 cases of respiratory disease, and 1.3 fatal cases of pneumonia.

It must, however, be said that the above statistics refer to too dissimilar periods to be accepted without reserve.

Aufrecht, of Magdeburg, is said to have found among the workers of a slag mill, studied for two years, a very high incidence of pneumonia (48 per cent.) characterised by haemoptysis and a very serious mortality rate (37.7 per cent.). According to Enderlen (1892), quoted by Beintker, one-half of the Thomas slag workers suffered from inflammation of the lungs, with a mortality rate of 50 per cent., with a result that each year one-quarter of the workers belonging to this category die. Fatal cases of pneumonia from slag amongst agricultural workers have been reported by Roth, Borntrager, etc.

In Great Britain, serious epidemics of pneumonia due to or favoured by Thomas slag dust were reported in 1888, 1893, and
1900. In 1924, a fatal case of pneumonia was reported. An enquiry was carried out in 1907 by the Committee on Dangerous and Unhealthy Trades.

The Ballard enquiry, affected on the occasion of the epidemic which broke out amongst the grinders of Thomas slag at Middlesbrough, came to the conclusion that the pneumonia in question was not due to slag but to the fact that during the pneumonia epidemic the persons exposed to slag dust were more susceptible than others to this infection, which more often than not was of fatal issue.

An enquiry conducted by Collins in the mineral cotton factories has revealed the fact that these dusts caused irritation and itching of the skin, leading to dermatitis. When inhaled the particles in question cause bronchitis and cough ("slag-workers' cough"), and pneumo-silicosis. Collins, while examining workers in the packing department, noted that as soon as they began to feel ill they quit the work. Workers who periodically resume work are on the other hand very seriously attacked.

In France, an epidemic of pneumonia due to slag, with a very high mortality rate (44 out of 75 cases), was reported at Nantes, amongst the workers of a manure factory (Ollive, 1888). Other cases of pneumonia have been reported at Nantes by Monnier and Gautret, in 1921 and 1924.

Analogous cases of severe pneumonia due to dust containing lime were reported by Watkins Pitchford among natives occupied in the gold mines.

In 1923, the Dutch Thomas slag workers complained of fits of asthma, coughing, and abundant expectoration. Cases of skin ulceration (face, hands, feet) were reported amongst workers working in the rain.

Opitz reported (1920) that during the war women were employed in Germany in the slag mills. Whilst the monthly medical examination of the staff (1917-1918) revealed that the morbidity rate for respiratory catarrh was 5.7 for women as against 5.9 for men, it was also shown that the susceptibility of the women was more marked for serious respiratory disease (leaving out of account influenza), for they showed a rate of 36.8 against a rate of 27.9 for the men. The difference is still more marked for influenza. There was noted, in fact, for the men a general sickness rate of 31.1 per cent., and amongst the women 66.4 per cent., whilst in the Thomas slag department these figures rose to 73.3 and 93.

According to Wegmann, there existed from 1890-1893 in the district under the Zurich inspectorate a slag mill employing an average of five to eight workers. During the short period of its activity this establishment alone had two, if not three, deaths from pneumonia amongst its workers.

It is not only the workers engaged on grinding who are attacked. Leymann reports 4 fatal cases which occurred in a mill, 2 of which affected a locksmith and a warehouseman. In the same year 2 other fatal cases occurred amongst workers employed in discharging slag. In 1908, in one establishment, for an average of 108 workers engaged in manipulating Thomas slag which had disintegrated into dust, there were noted 67 cases of respiratory disease, 33 of which affected transport workers and 19 unskilled workers in the storing department. In 1912, there were reported 2 deaths of young girls employed in the workrooms for repairing the sacks.

The incidence of injury due to slag amongst peasants engaged in spreading this product over the fields is well known (conjunctivitis, oedema of the glottis, pneumonia, etc.).

Statistics relative to transport workers are unfortunately not available.
of attacks on different foci resembling clinically in such cases the pneumonia known as broncho-pneumonia.

The lesions met with in post-mortem examination reveal the following conditions: multiple lesions of recent bronchitis clear and accentuated, vaso-dilatation, sometimes ulceration and perforation of the bronchial tissue which is, as it were, destroyed by a physico-chemical traumatism from the slag dust, which constitutes a lacerating agent of the first order; multiple pulmonary lesions of different natures in the same patient: simple congestion, grey hepatisation centres, sometimes veritable excavations filled with blood which lead to anatomo-pathological diagnosis of abscess of the lung. Almost always there are found adhesions and exudation of the pleura. It may therefore be said that the lesion in question presents a clinical picture varying from ordinary pneumonia to broncho-pneumonia accompanied by abscess of the lung.

Bacteriological analysis has revealed the presence of the pneumo-bacillus of Friedländer and isolated or associated pneumococci as well as other usual micro-organisms of suppuration.

Chemical analysis has demonstrated the presence of slag dust on the tissue of the bronchial tubes and the alveolar endothelium.

The interpretation given to this condition varies according to the opinion of different authorities. As a result of animal experiment, it might be deduced that lime, phosphoric acid, etc., and slag dust exercise a caustic and wound-ing action on the respiratory apparatus in such a way that the mechanical lesions resulting therefrom become the starting point for acute conditions and penetration of pathogenic germs. This view, which has in its favour arguments of considerable probability and even certitude, is taken by Attimont, Gautret, Agasse-Lafont, Heim de Balzac, Loeb, Briault, and quite recently (1924) Brelet.

Other authorities think that the dusts in question only cause the ordinary effects of normal pneumoconiosis, cutaneous lesions — nasal and bronchial — which follow a chronic course, and that pneumonia is only a condition superimposed on favourable centres. This is the view of Brouardel, etc. Excessive work, fatigue and strain, exposure to variations of temperature and perhaps also a tendency to alcohol-ism, etc., favour the development of the disease.

The so-called epidemics are only in reality the simultaneous appearance of similar symptoms among workers ex-
posed to the same causes. The occurrence of contagious disease never in reality arises.

According to Heim de Balzac and Agasse-Lafont, it was wrong to designate the cases in question as “slag pneumonia”, and it is this error which gave rise to the arguments just summarised.

If cases of slag pneumonia are analysed in detail the following differences are noted between it and ordinary pneumonia: more diffused physical signs, association with signs of bronchitis, inflammation of the lungs, spittle hardly ever rusty, etc. On the other hand, very acute conditions are characteristic of the workers in question. This is proved by the high incidence of cases, their repeated occurrence among the workers, their frequent incidence among new workers, and the clinical anatomo-pathological and experimental data assembled.

PROGNOSIS

Prognosis is very serious. The high mortality among the persons affected has been referred to above. If the patient recovers, convalescence is long and difficult and pulmonary symptoms remain: purulent expectoration, recall-

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The enquiry conducted by Collis in the mineral cotton factories of Great Britain revealed the fact that in general workers become fairly easily acclimatised to the irritant action of the dust, but that before this happens they suffer from conjunctivities, eczema, sometimes haemoptyses, and general discomfort, with the result that many of these workers very soon quit the occupation. It is not, however, a question of serious lesions, and among workers who have worked in these factories for a long time there is noted only a diminution in chest expansion without signs of organic degeneration or tubercular infection.

HYGIENE

The prevention of injury is best attained by the application of measures taken for avoiding risk due to harmful dusts. Thus, for example, it is essential to employ exclusively adult men, and to limit the duration of their daily work. The flooring of the workrooms should be impermeable, cleaned at regular intervals by flushing with water or, better still, by means of mobile vacuum cleaners.

Technically there is also applied as a means of prevention granulation of the slag under a jet of water to prevent liberation of the injurious dusts. This operation, however, gives rise to the production of sulphuretted hydrogen, which must be removed in an adequate fashion by means of good ventilation. All the operations (grinding, crushing, sieving, bagging, transport, etc.) should be effected in closed airtight receptacles provided with efficient localised exhaust devices. Packing especially should be done in sacks of dustproof material. There has been recommended in this connection the use of paper sacks, which, however, was subsequently abandoned (Austria). The use of jute sacks is usually preferred. Transport should be effected mechanically in closed apparatus provided with exhaust devices. The very fine dust given off during the various operations is withdrawn by a ventilator which conducts it to a storing room. Storing of the slag should be effected in wooden silos separate from the workrooms, hermetically sealed under slightly negative pressure in order that the dust may be easily evacuated during the packing operations.

Experience has shown that in well-regulated establishments dust is given off only during loading of the first crushing machines. This disadvantage can be overcome by assuring the airtight closing of the apparatus and the installa-
tion of a well-thought-out exhaust device placed around the loading funnels.

In a German factory a good dust removal device was the means of reducing mortality among the workers from pneumonia from 28 to 1.2 per cent., a figure which is, however, twenty times higher than that for workers in other industries.

Measures of personal hygiene comprise the following: washing accommodation, douche baths, provision of working clothes including caps, where necessary adoption of respiratory masks, intervals during the course of the work spent in fresh air or alternating shifts for workers in the various departments of the factory, prohibition of carrying food into the workrooms, provision of canteens.

Medical examination should be required on starting work with a view to elimination of workers predisposed to respiratory disease (strict examination of the nose and throat), and periodic medical examination required thereafter to supervise the state of health of the staff.

As a protection for the transport workers the only effective measures are the use of airtight sacks (jute, oiled paper) and especially mechanical means of transport (loading and unloading). In Austria the powdered slag is usually acidified with an excess of sulphuric acid which renders the product hygroscopic, slightly sticky, and makes it adhere to the inside of the sack, rendering the latter completely dust-proof.

**Legislation**

Women are excluded in Germany from workrooms into which slag, ground or otherwise, is brought in packing material. In the Netherlands they are excluded from workrooms in which there is exposure to dust during grinding and sieving.

Youths under eighteen years of age, as well as women, are excluded in Germany from the above operations as well as from the work of shaking empty sacks, and in the Netherlands from all workrooms where the atmosphere is contaminated by slag dust.

Youths under sixteen years and women under twenty-one are excluded from manipulation of slag in Spain.

In Germany an Order of 25 April 1889 demands that slag mills should adopt detailed measures of hygiene (protection against dust, personal hygiene). This Order was amended on 15 November 1903 (duration of work), in 1911 (texture of the sacks) and in 1914 (technical improvements). In France there are no special edicts, but that of 29 November 1904 provides for the application of somewhat similar health measures to those usually applied in dusty trades. In Great Britain recommendations were formulated by the Committee on Dangerous and Unhealthy Trades in 1907.

In the Netherlands the law demands compulsory notification of cases of dermatitis and of respiratory disease due to Thomas slag.

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**Basket Weaving**


The plaiting of vegetable fibres—branches, tendrils, stalks, weeds, bark, strips of fibre, chips — somewhat in the method of weaving, is engaged in to furnish a vast number of products, and consequently forms the basis of various industrial processes more or less developed amongst civilised nations as well as amongst savage races.

In this way are produced large articles such as baskets for use in mines in the coal trade, transport work, and factories, fine articles such as small household baskets, sieves, basket bread moulds, and other household utensils, luxury articles for florists and confectioners, articles of furniture (seats, tables, armchairs), basket work used in coach building (in cane or wicker firmly woven).

The material to be worked up is of vegetable origin and is derived from a large series of plants, and is mostly long, supple and cylindrical in form, sometimes threadlike, ribbonlike or in lamiae, offering a remarkable degree of resistance and a sufficient degree of flexibility to permit of being bent, twisted, rolled, or plaited. With the material in question fragile objects are covered and protected, as for instance
flasks; or, on the other hand, it may serve in making certain objects such as ropes, matting baskets, hats, etc.

The plants employed vary according to the object to be made and also according to the local vegetation available; in general it is the more flexible part of the plants that is employed, plants which grow in damp valleys and also marsh plants and marine plants such as the alga. The raw material of such industrial processes consists of the actual and veritable matting material such as corn straw (Triticum aestivum), rye straw (Secale cereale), straw from oats (Avena sativa), from buckwheat (Fagopyrum vulgare), from rice (Oryza sativa), from grass (Typha latifolia), from sword grass (Carex riparia), from salt grass (Carex caespitosa), from rushes (Sphagnum holochyronus, Scirpus lacustris), willow branches (Salix viminalis, Salix purpurea, Salix alba, etc.), raffia (Raphia textilis), jute fibre (Corchorus olitorius), the cocculus plant (Coccus nucifera), malacca cane (Calamus Rotang), etc., and fairly often and for certain objects the raw material is also in part composed of pieces of wooden framework to constitute the basis of these objects, as, for example, the sides, edges, bottoms and handles of baskets. These elements used for support are much less soft and pliable than the woven parts and come from various plants both with short and long stalks and even at times from hard wood plants. When this is so, strips, laminae or bands are cut from the trunk of the shrub parallel to its widest axis with a length of 2-3 metres, 2-5 centimetres wide, and some millimetres thick. Besides the framework these rough hard woods are also sometimes used for weaving, for instance, certain coarse types of baskets.

The basket-weaving industry is domestic in character and often gives occupation to a whole family; much of it is done by women, whom the employers provide from time to time with the raw material and who work in their homes, in courtyards or in the open doorway of their houses, with irregular hours; it is fairly rare for the women workers to congregate in some small, poor, and more often than not unhealthy, workplace, provided by the small employer. In either case the gain is in proportion to the amount of work effected, piecework being the system followed. Proper industrial establishments are rare, except sometimes in the case of the production of straw hats, though even this work also is principally domestic, at least the branch of the industry with which this article is concerned, that is to say, plaited straw hats and hand sewing of these plaited strips for making into hats.

As a general rule in this kind of work, the finest and consequently least tiring work involving manipulation of the most flexible and softest materials is consigned to women, and the coarser work (baskets of various types) requiring manipulation of harder and heavier material is entrusted to the men. Thus at times the framework of an object and the warp, so to speak, is made by a man, while the more delicate work of making the woof is done by a woman; such a division of labour is followed for instance in making basket-work coverings for large bottles. As an illustration of this class of work may be taken the covering of wine flasks, domestic work usually effected by women and widely engaged in in the wine-growing districts. The Tuscan flask-coverer winds by hand a strand of straw or salt grass (Carex caespitosa) round the body of the flask, emerging from the foot upwards towards the neck; thereafter, using a metallic needle (25-30 centimetres long) having the form of a flattened lance, with a blunt point and a large eye, the worker draws strands of sword grass (Carex riparia) round the body of the flask, emerging from the foot upwards towards the neck, both obtained from the same vegetable fibre.

Pathology in regard to this occupation is similar for all workers despite the varied forms of production; it is entirely a question of affections of the hands and is always related to the type of raw material used, being directly connected with the degree of softness, smoothness and flexibility of the latter.

Prosser White refers to the enlarged hands of basket makers with transverse lines and thickening of the closed fist. The thumb is covered with horny skin and is likewise flattened and enlarged (pressure against the fibre). Teleky has also described deformation of the hand consisting of curvature of the first and second phalanges of the fingers of the right hand bent towards the cubital edge.

Flask-makers show callosities, flat and not deep seated, chiefly found on the cubital edge of the first phalanx of the little finger extending to the styloid apophysis of the ulna on the two hands, but particularly on the right hand; less thick and extensive callosities are seen

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on the thenar and hypothenar eminences and on the palm side of the first phalanx of the first fingers, and fairly small callosities on that of the second phalanx. On the contrary, at the base of the palm of the right hand on the carpo-metacarpal joint is found a profound callosity one or two centimetres in height and extending parallel to the width of the hand by the end of the large needle used, as stated, for the outer covering and for fixing the support and the handle of the flask. The needle is pressed against the carpo-metacarpal region with a view to pushing it up from the base to the neck of the flask while it is pressed down from the neck to the base by being grasped by the forefingers. These upward and downward movements are repeated round the flask as if to provide a wide border. The flaskmakers sometimes wound the radial edge of the left hand with the point of the needle (especially corresponding to the thenar surface), since they hold the neck of the flask firm with the left hand while pushing the needle with the right.

The palmar callosity near the pulse already described is typical of flaskmakers since it is due to the use of the needle and wowers who weave vegetable fibres present callosities on the hands varying as to disposition, form and thickness, according to the quality of the raw material used in weaving, according to the particular movement of the hand involved, and in some cases according also to the particular tool employed — for instance amongst straw weavers sewing straw hats, who rub away the edges of the first two fingers of the left hand by repeated piercing with the needle.

It would take too long and be unduly monotonous to enumerate the form and disposition of all the callosities met with on the hands of the different categories of weavers of vegetable fibres (makers of baskets, large and small, matting, straw rope and string, small luxury objects in basket work — fans, cigarette cases, etc.). On the contrary, it is worth mentioning that some of these workers and precisely those who employ natural or artificial materials of a resistant nature such as rushes (Juncus conglomeratus, Juncus inflexus) or bands of chestnutwood (Castionea sativa) for making the framework or bottoms of baskets or fine chips for making ropes (g. Pinus) or again those who use soft flexible materials with fine pointed and cutting edges such as certain rush plants (g. Carex) suffer from cuts. Wounds caused by such materials are almost always slight, but are characteristic of certain categories of workers engaged in making baskets, rope, and petrino cloth and generally the workers cuts are mostly found on the palmar surface of the phalanges of all the fingers and less frequently on the thenar and hypothenar eminences, extending beyond the respective radial and cubital edges. They are almost always inflicted close to the epidermis and rarely to total thickness of the cutaneous tissue; as, however, may be readily understood, the seriousness of the wound depends on the kind of material used and is in direct proportion to its hardness, asperity and particularly the fineness of its cutting edge. Cuts inflicted by any materials used are always numerous, even to the extent that they cannot be counted, on the hands of workers who have for long been engaged on such work; they are darkened with deposits of foreign matter, while the more recently inflicted show side by side with healed cuts and are characteristically disposed perpendicular to the major axis of the hand and parallel to each other, being caused by the drawing across the skin of threads or bands of vegetable fibres held tightly in the closed hand. These linear wounds with clean edges one centimetre or more in length do not cause much trouble to the workers when they are superficial; when more profound they bleed and sometimes require a protective bandage; rarely they set up troublesome and persistent fissures; only in exceptional cases do they suppurate. Workers who meet with such wounds as the latter, and more especially those with suppurating wounds, are obliged to quit their usual work (especially in winter), while women workers are rendered unfit for domestic tasks such as washing dishes and laundry work. Wounds caused by cut edges met with on the back of the hands, and when this is the case they are mostly pricking wounds or stabs due to violent contact of the hand with the raw material in the act of withdrawing it from the bundle or mass in which it is received. Among individuals who definitely quit the occupation in question traces of superficial wounds disappear, but those of more deep-seated ones remain. Almost all the raw material in question is used while still fresh from recent harvesting or else dampened and is therefore incapable of producing dust. Yet some of these materials, such as strands of chestnutwood, branches of hazelwood (Borjuz avelana) — containing tanning substances as well as the fresh and humid wood — may exert a chemical action on the skin of the
Calamus Rotang or Draco. and on the mycetes found on cutaneous Spergillus glaucus, etc. are: Mucor mucedo, Rhizopus nigricans, semination of moulds. stripping, precaution is to damp the reeds before place a newly formed epiderm. A useful weeks the crusts fall, leaving in their stages. These lesions, which never develop into pustules, break easily, and cause pur- erythematous patches which tend the body which it reaches. liable to set up lesions on the parts of wounds, specific infections. Amongst this class of affections may be mentioned the disease of the Pro- vocation causes of the larynx. Certain cutaneous eruptions apart from chemical action may be produced by mechanical causes; such for example is the case with the leaves of a rush plant (Carex maximus), which has fine sawing and cutting edges rendered harder by the abundant silica content of the superficial cells of the wood. Layet has reported chronic gingivitis amongst basket makers, mostly accom- panied by labial herpetic, which he attributes to the bad habit of holding tightly between the lips little strips of wicker or of sucking the end of these. Among workers engaged in the more delicate processes of manipulating vegetable fibres such as weaving, making basket-flask covers, but much more rarely amongst those engaged on the coarser operations, such as making large baskets in all forms, occupational cramp is met with, spastic and painful in character and localised on the hands, sometimes affecting even the forearm. Individuals thus affected re- cover usually after rest, but readily suffer a relapse on resuming work. In this connection Layet remarks that while the sedentary work of basket makers is not tiring, workers of this class are nevertheless afflicted with all the troubles incident to a sedentary life and limited occupational movements effected by the arms; lumbago, digestive and respiratory derangements are frequently noted amongst them. Attention has likewise been called to localised and general troubles (af- fections connected with cold, rheumatism) to which workers who themselves gather
the reeds and willows required for their occupation are liable.

There should likewise be mentioned in conclusion possible injuries due to burning of sulphur in the process of bleaching certain fibres or to the use of turpentine, and of various solvents or lacquer and varnishes and of colouring materials for decorating certain basketwork articles.

As regards prophylactic measures in relation to the lesions mentioned, the use of gloves to prevent cuts and cracks is advisable; many workers however declare that precision of movement of the fingers is hindered by gloves. Men who, as has been stated, mostly handle coarse vegetable fibres protect their hands with bits of cloth and skin, placing a kind of digital palmar lining on the parts most exposed to rubbing with the raw materials.

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Benzene (Benzol)

Benzol is given off during the distillation of coal in a closed vessel. It is formed partly in the tar deposited in condenser boxes or towers (see articles “Gas Works” and “Pitch”) and another — the most important — part remains in the gas. There are, therefore, two means of recovering benzol: (a) tar distillation; (b) stripping the gas.

(a) Distillation of tar.— This has been for long the sole source of benzene. The first fraction in the distillation of tar constitutes the light oils containing water and benzol, given off up to 170° C. After separation of the water by decantation they are brought into contact with dilute sulphuric acid which removes the basic substances (pyridine and homologues) liberated subsequently by treatment with lime, then with concentrated sulphuric acid which combines with the ethylene hydrocarbons and the sulphur impurities. They are then washed with soda lye to eliminate the phenols, leaving the crude benzol which is rectified in a continuous apparatus made up of three fractionating columns allowing of methodical separation, on the one hand, of the lighter products and, on the other, of the pure benzene and pure toluene, while the residue (solvent naphtha) falls back into the lower part of the last column.

Colourless, mobile, very refractive liquid with an agreeable, characteristic smell. Burns with a luminous but very smoky flame. Distils completely between 80° and 81° C. Density 0.874 at 20° C.; boiling point 80.4° C. If cooled below 0° C. it crystallises in large rhombic crystals.

Extremely volatile, especially if slightly heated. The vapour is three times as heavy as air; easily explosive in proportions of 2.6 to 6 per cent. of air (optimum 2.7 parts to 63 parts air).

Slightly miscible with water, more so with alcohol (ethyl, methyl), ether, acetone, chloroform. Easvly electrified, it is self-inflammable. Textile materials in baths, if benzol is set in motion or agitated, become positively charged and the benzol negatively.

Never chemically pure in the commercial state; even when purified it contains traces of xylene, phenol, toluene, etc. Obtained pure by freezing or by distilling benzol acid (distilling with lime according to the reaction

\[ C_6H_6 + CaO \rightarrow C_6H_5Ca + CaO \]

washing the distillate with caustic soda, drying with chloride of lime) or synthetically starting with acetylene or other aliphatic hydrocarbons (by passage through a glass tube heated to redness).

Manufacture

Benzol is given off during the distillation of coal in a closed vessel. It is formed partly in the tar deposited in condenser boxes or towers (see articles “Gas Works” and “Pitch”) and another — the most important — part remains in the gas. There are, therefore, two means of recovering benzol: (a) tar distillation; (b) stripping the gas.

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The term "Benzol" is generally confined in French to the mixture of benzene and its homologues obtained from the distillation of tar. Petroleum essence is sometimes erroneously called "benzine".
(b) Stripping the benzol from gas.— In coke ovens the extraction is carried out by means of towers where a great surface is provided with several layers of wood laid cross-wise. The gas travels from below upwards, while the heavy oil, coming from the distillation of the tar, trickles down in the apparatus. The benzol dissolves in the heavy oil and is separated from it then by a current of steam.

The benzol caught in the steam is carried to the top of the fractionating column at a temperature of about 100° C. and then into a condenser where it is cooled to the ordinary temperature.

The heavy oil can be used again, but after several operations the tarry products with which it has been enriched have to be distilled out.

In gas works recovery of benzol from the gas is not carried out, as to do so would mean removing too much of the heating value and especially of its illuminating power. However, many circumstances have rendered this procedure profitable (enrichment by carburetting, use of incandescence mantles for lighting, extension of electric lighting with, as a result, almost exclusive use of gas for heating purposes).

Traces of benzol are found in the tar and still more in gas from the distillation of peat, and also in American and Caucasian petroleum. The petroleum of Burma, Borneo, Java, Sumatra and Japan are mixtures of aromatic hydrocarbons that can be easily separated. The fatty hydrocarbons of petroleum can yield benzol and toluene by the process of "cracking" (see article "Petroleum"): treatment by heat at 500°-1000° C. under pressure and in presence of a catalyser.

In commerce different types of benzol are distinguished:

(a) Crude 90 per cent. benzol (density 0.86-0.88), which distils up to 100° C. and contains about 84 per cent. benzene, 13 of toluene, 3 of xylene;

(b) refined 90 per cent. benzol;

(c) 50 per cent. benzol (density 0.88), of which 50 per cent. distils at 100° C.

These benzols contain also other products such as bisulphide of carbon (0.2 to 1 per cent.), thiophene (0.1-0.2 per cent.), ethylene and other impurities: olefine, naphthaline, paraffin, etc.

A benzol is also found in commerce which contains no benzene and of which the composition is about as follows: toluol 25 per cent., xylol 70, higher homologues over 5; and also a heavy benzol which is composed only of higher homologues (95 per cent.) and xylol (5 per cent.).

CAUSES OF INTOXICATION

These represent a very important practical problem, because the majority of the acute and subacute cases are fatal.

A. In the course of manufacture (gas works, coke ovens, distillation and purification of benzol).—Intoxication is rather rare in modern installations. The construction and working of the apparatus are so closely supervised that practically there is no danger either of fume or of contact with benzol. In regular working, leakage or defects in upkeep of the apparatus become evident immediately by headache and slight vertigo among the workmen. The severe and fatal cases are nearly always the result of mistakes in working or of work carried out hurriedly (workmen engaged in emptying or cleaning, painting, or repairing boilers or other apparatus that has served for the preparation or transport of benzol in the absence of sufficient ventilation) or to pure accidents (explosion, the upsetting of quantities of benzol, etc.). Hence the absolute necessity of taking indispensable precautions under the responsibility of a manager and organising staff carefully trained in the carrying out of regulations designed to prevent accidents.

Because of its aromatic smell many workers do not regard benzol as poisonous, associating the idea of danger rather with a smell at once irritating or unpleasant. Cases are reported of workmen drying their hands soiled with benzol on their clothes, which thus provide a large surface for the evaporation of the poison in closed or small workrooms. There should be borne in mind also, as sources of danger to persons employed in the making of benzol, carbon monoxide, hydrogen sulphide, etc.

B. When used industrially.—Despite its toxicity, benzol is largely employed (a) as a chemical product (preparation of the aromatic derivatives), (b) as a solvent (it often replaces less powerful solvents of the fatty series), (c) as a fuel or carburetting substance.

(a) As a chemical product: Manufacture of the derivatives of benzol (nitro-benzene, etc.), phenols, anilin, anilin colours, and other colouring matters (where it is purified by fractional distillation), pharmaceutical products,
permanences, explosives, etc. (see the corresponding articles).

(b) As a solvent for iodine, phosphorus, etc. Industries for the extraction of fat: Dissolving fatty substances, oils, etc., for extracting fat from bones, coconuts and soya beans, etc. Artificial manures, Glue factories. Textile industry (manufacture of silk ribbon, finishing department). Cementing and finishing of shoes. Artificial leather and feather industries. Spreading textiles with "fabrikoide".

Manufacture of straw hats.

Indiarubber industry: Preparation of solutions for "rubber cement" (making of pneumatic tyres). Substances for waterproofing tissues. Aviation industry: doping the wings of aeroplanes with acetate of cellulose dissolved in hydrocarbons (solution containing 40 per cent. of benzol (see article "Tetrachlorethane"). Industry of impermeable rubber goods: 250 grm. of rubber solution containing about 200 grm. of benzol. Every person employed uses on an average 300-350 grm. of benzol or benzene per day. A solution of rubber containing 30-35 grm. of benzene and 65-70 grm. of carbon tetrachloride is also used in the making of ladies' hats as a cement in place of needle work. Manufacture of cardboard boxes, etc.

It is used further in the linoleum, celluloid and lacquer industries, in factories for making electrical fittings, in painting, in decoration (e.g. pottery), in bronzing and gilding. It is combined with tar paints or in the making of quick drying paints widely sold commercially under fantastic names; it is used in varnishing the interior of reservoirs, vats, special apparatus, interior of ships, etc. It is used in accumulator works, bronzing, decoration of pottery, gilding, lacquering, in varnishing (especially of motor cars) and even for the removal of paint (e.g. church benches) (see article "Painting"). It replaces also turpentine, as a solvent of asphalt.

In the dyeing industry benzol is used for degreasing, mordanting and dry cleaning. In the most varied undertakings (mechanics' workshops, optical glass manufacture, printing and allied industries, etc.) it is used in the place of pure benzene for cleaning purposes.

(c) As a fuel. Motor propellant: as a carburetting agent in place of petroleum benzine; as an illuminant: used in lamps; its toxic action in this respect is like that of other gases giving off especially CO (see article "Petroleum"); as a carburetter of illuminating gas, of water gas (see articles "Carbon Monoxide" and "Gas-Works: Water Gas, Illuminating Gas"). It is mixed also with alcohol for lighting purposes which denatures it at the same time. In engineering, it is used to solder alloys (boxes of white metal, electrical apparatus).

It is used in place of acetylene for autogenous soldering and cutting up of metals, and as the constituent of certain anti-rust substances.

DANGER OF EXPLOSION AND FIRES

The mixture of air and benzol vapour in certain proportions is explosive. The heavy vapour sometimes travels along the ground to a point where a flame sets it alight and, forming a kind of bridge between the flame and the source of the vapour, gives rise to fires or explosions.

TOXICITY, ABSORPTION, ELIMINATION

The light oils come on the market under the commercial name of "benzine", and too frequently this leads to confusion with petroleum benzine, so that even in toxicological literature confusion between the two products is not unknown (see article "Petroleum"). The divergencies are probably due to the nature and quality of the impurities of the two substances (carbarylamines, carbon bisulphide, thiophene) and especially to the differing conditions under which intoxication has taken place. But it is very much to be desired that, as far as possible, essence of petroleum (benzine) should not be confused with benzene (or benzol).

Benzol has action on cellular protoplasm, the blood, on the haematopoietic organs (characteristic and dominant in the acute cases); the central nervous system (very striking: narcotic action analogous to that of chloroform and dominant in the acute cases); on the heat-regulating mechanism of the body (lowered temperature, sensation of cold in those intoxicated), and on the oxidation processes of the organism (limiting them). (For the local action, see below.)

The toxic action of benzol in subacute and in chronic cases is said to be as follows: degenerescence of the constituents of the blood and haematopoietic organs (the liver, kidneys, etc.); atrophic action on the bone marrow (on the leucoplastic portion and especially the granulocitogenic or erythroblastic tissue), on the spleen and the lymph glands, causing leucopenia (as a result of the destruction of the leucocytes and
noted long ago; coagulation is retarded.

progressive

involves even 600 per cubic millimetre (an early and may even disappear. After a short time showing important morphological changes or young and immature forms.

840,000 and 600,000 without at the same time showing important morphological changes or young and immature forms (only in experimental massive intoxication has an intense excessive cell formation been observed and shown to be genuine by the formation of new elements). Blood plates are diminished and may even disappear. After a short period of leucocytosis (excitation of the leucoepoietic organs) characteristic leucopenia sets in down to 1,100-850, and even 600 per cubic millimetre (an early sign, if accompanied by diminution of the red blood cells and haemoglobin); colour index is sometimes above unity, (anaemia of pernicious type), sometimes below (chlorotic type). The leucopenia involves especially the polynuclear neutrophiles which may disappear (tendency to or existence of an inversion of the leucocytic count with relative lymphocytosis). Methaemoglobin is absent. Clinical data, therefore, do not justify a picture of pernicious anaemia nor of haemorrhagic aleucaemia (as certain German writers maintain), because the blood is damaged in toto and the picture left is that of a grave progressive anaemia of aplastic and haemorrhagic type.

The blood is markedly fluid, a fact noted long ago; coagulation is retarded and the blood has a pink colour as in poisoning by carbon monoxide.

Toxic dose.— Experiments on animals go to prove that benzene vapour is toxic in the proportion of 0.015-0.016 per litre of air (Ramboseux). Chronic poisoning is said to result from daily dose of 9 mg. per litre of air in the course of 23-25 days (Lehmann). With benzol (commercial) this author has shown that 20 mg. of the vapour per litre of air was fatal to the animal in two hours, that 40 mg. produced the same result in 30 minutes, 60 mg. in 15 minutes, and 120-140 mg. in a few minutes. In order to induce narcosis of moderate intensity, i.e. to bring about diminution of the reflexes, a dose of 20 mg. of the vapour per litre of air for six hours is sufficient; 40 mg. for two hours and 60 mg. for one hour.

In man a dose of 10 mg. of the vapour per litre of air (in volume a proportion of 3 to 4 per cent.1) causes marked discomfort; 15 mg., after 30 minutes, sensation of fatigue, discomfort and mental confusion; 20-30 mg. after some hours can induce loss of consciousness. Fatal cases, nevertheless, are described in persons working in a room where analysis has shown only 1 part per 1,000 of benzene, and severe cases, with loss of consciousness where a proportion of 2-3 parts benzene to 100,000 parts of air has been found.

Heated vapour is the more dangerous, especially in a badly ventilated room.

As has been said above, benzois include very different products (hydrocarbons both of the aromatic and acyclic series). The most important practical point, still much discussed, is that relating to the difference in toxicity (if any) between pure benzene and commercial benzol.

Researches into this point are not numerous but the results are very different. According to some writers intoxication is more marked and more pronounced with minimal concentrations of the vapour in air of crude benzois than with commercial benzois, and with these than with the pure product. Other writers have not noticed perceptible differences in the action of different benzois. Some attribute the toxic action to the toluenes, the thiophenes, or the substitution products containing benzois; others again (Kobert) to the presence of cyclopentadiene (C, H) contained in crude benzo; and yet others to the benzol itself. But some authorities have found in animals signs of toxic action with benzene (chemically pure, which is not the case with benzol as ordinarily used in industry) earlier than with common benzol. This paradoxical result can be explained by the fact that volatilisation is the more rapid the purer the product.

No opinion beforehand can be expressed as to individual idiosyncracy or degree of susceptibility in regard to the poisonous action of benzol. Even in animals of the same species susceptibility to the poison varies very much. It should be borne in mind that slight poisoning can have grave sequelae.

1 That is 10 grm. of benzene per cubic meter: 3.3 grm. of benzene vaporised at ordinary pressure and temperature occupies a volume of one litre.
Recent experiments show that animals subjected several times to the vapour of benzol become hypersensitive and display symptoms of acute intoxication from small doses of benzol which were readily tolerated at first. This is a fact of prime importance as explaining intoxication in persons who had not before shown symptoms.

Susceptibility to intoxication is increased by well-recognized conditions, but especially by respiratory maladies (tuberculosis), kidney disease (which hinders elimination of the products of oxidation of the poison), by pregnancy, and youth.

Note the kind of respiration of the person, former intoxications, sex (women are very sensitive), the fact that the vapour is less well borne on days following a rest and in sultry weather, or when rapid weather changes occur, because of the defects in natural ventilation existing as a result of these conditions.

Absorption takes place especially by way of the respiratory tract (inhalation of the vapour); this is the case with the acute and subacute forms. In chronic cases absorption by the skin may be accepted. In the opinion of some writers this does take place and, at any rate in part, even in the form of vapour. But this channel really plays only a secondary role, and the quantity of vapour thus gaining access to the system must be minimal as compared with that inhaled. Absorption by the skin evidently is facilitated by abrasions, scratches, etc., either pre-existing or set up by benzene itself (remember the property of benzene of dissolving fatty substances and so altering the epidermis). In practice skin absorption is generally very restricted. Intoxication by way of the digestive tract can also be considered.

According to Lehmann, the proportion of the poison retained by the human system is very high, namely 80-84 per cent. of the benzene contained in the atmosphere.

Elimination.— Benzene is mostly eliminated unaltered by the respiratory tract. It is easy to detect the characteristic smell in the expired air. Benzene has never been discovered either in the organs or the urine; recently, however (1923), in America it is said to have been found by a special method in the cadaver. It must, therefore, undergo changes in the organism (very different in different subjects) as to the nature of which very little is known. The products of its oxidation are represented especially by phenol (30-40 per cent.), pyrocatechol, hydroquinone, products which are eliminated by the urine as sulphates. Elimination proceeds usually very slowly.

The urine may contain further albumin, cylinders, droplets of fat, and haemoglobin.

Statistics

A complete account of the acute and chronic cases of benzene poisoning cannot be given. It is possible, however, to recall the majority at least of the cases recorded in medical literature. Rambousek (1911) describes 34 cases of acute poisoning, of which 22 proved fatal. The Factory Inspectors reported, in 1911, 2 fatal cases in Austria; 2 cases (1 fatal) in Switzerland; in 1912, 3 cases with two deaths in Germany; 3 cases with one death in 1913. Chronic cases are not reported to the Factory Department in Great Britain. Include also cases due to petrol and naphtha, which numbered 6 in 1913 (with 2 deaths), 4 in 1914 (2 deaths), 4 in 1917 (2 deaths), 7 in 1918 (4 deaths), 9 in 1919 (3 deaths), 12 in 1920 (1 death), 10 in 1921, 25 in 1922 (1 death), 55 in 1923 (3 deaths), 26 in 1924, 3 in 1925, 4 (1) in 1926 and 7 (2) in 1927.

In 1922, in a German factory for the manufacture of rubber shoes, 22 persons showed symptoms more or less acute; 16 workers were affected three days later. In the same factory in September 1923, 27 persons showed the same symptoms of acute benzene poisoning. In January 1924 two workers in a cardboard box factory, after being exposed to a solution of cement were also intoxicated by benzene.

The National Insurance Office of Lucerne in Switzerland reported 37 cases of poisoning and 11 of eczematous ulceration due to benzene (and its compounds) in 1918; 4 of poisoning and 1 of ulceration in 1919; 12 cases and 1 respectively in 1920; and 7 and 2 in 1921.

In Bavaria 10 cases from use of lacquer (of which the solvent was benzol) came to the knowledge of the Medical Inspector of Factories in 1914-1918.

During and after the war the production and use of commercial benzol became so important that cases of poisoning became more and more frequent and severe. Inspectors of factories drew attention specially to the danger of intoxication among painters applying colours dissolved in benzol heated to 60° C. in confined spaces on board ship, to the use of benzol in washing optical glass (Austria), and especially among workmen engaged in the manufacture of rubber goods where a number of cases of subacute poisoning occurred.

Chronic Poisoning.

The first cases were described by Sanning in 1897 in Upsala among nine women between the ages of 15 to 20 employed using benzol as a solvent for rubber (for periods varying from three weeks to four months). In 1910 Selling...
described 3 cases affecting girls between 14 and 16 years of age employed in a factory in Maryland, U.S.A., and in 1911 two other cases. Holtzmann has studied the cases in men, but it is especially women who are most exposed to intoxication from benzene.

In 1916 McClure described 3 cases in a Maryland factory; in 1917 Harrington, of Boston, reported 5 cases (with 3 deaths); 2 fatal cases after three months' use of a benzol solution occurred in Edinburgh; a third fatal case in the same factory occurred in 1918. The New York Commission on Compensation for Accidents in 1920 reported 2 fatal cases in the manufacture of “fabrikoide”; in 1922, 5 fatal cases came to light among persons making rubber goods in Milan (Ronchetti Meda), and 10 cases among women described by Starr; 2 other cases were described in 1923 by Brücken (Germany), who had also reported 2 industrial cases in 1922. Further cases have been described by Gerbis (Germany), Flandin and Robert (France), 2 fatal cases by Hamilton (U.S.A.), and others in the reports of the inspectors of factories of different countries (see also the report published in 1922 by the Department of Labour of Massachusetts: Cases of Benzene Poisoning in the Manufacture of Rubber).

SYMPTOMS

Poisoning presents itself as acute, subacute and chronic.

(a) Acute or fulminating form.— Fatal issue at the end of a few minutes, due almost always to inhalation of massive doses of benzene vapour. Profuse sweating, hyperaesthesia, hallucinations, delirium, coma, death.

The clinical picture varies much according to the quantity of vapour inhaled and the predisposition of the subject: vertigo, headache, excitement recalling the first stage of acute alcoholism, cough, dry skin, flushed face, subnormal temperature, etc. In severe cases there follows a stage of depression, with general malaise, nausea, vomiting, somnolence, mental hebetude, loss of consciousness, tremor, respiratory and circulatory troubles, sensory and motor paralysis, pink mucous membrane. The narcotizing action of the poison can reach a high degree with complete general anaesthesia, abolition of reflexes, and death in a state of coma.

If the person has inhaled massive doses, death ensues in a few minutes or fairly rapidly (30 minutes to 1 hour). Recovery from severe intoxication, however, can take place rapidly and without sequelae, but on the other hand slight cases may recover and yet be associated with very severe and prolonged sequelae.

(b) Subacute and chronic form.— At first the individual tolerates the poison easily, or at least seems to do so, over a period of weeks or months. A time comes, however, when he complains of headache, malaise, somnolence, gastralgia, vertigo, feeling of cold, rapid onset of fatigue, formication, anorexia. These are the signs in slight cases. Next, or in the more severe cases, are noted: need for coughing, shortness of breath, fever (sometimes high), remarkable anaemia, livid skin, and, what is characteristic in these cases, multiple haemorrhages underneath the skin (localised on the upper and lower limbs as in purpura haemorrhagica, more or less extensive according to the gravity of the case and the individuality of the victim) and in the mucous membrane (nasal, intestinal, gastric, renal). In women there is very abundant menstruation, especially during the extra-catenal period or during pregnancy (very frequent and early symptom, often the only one). Scorbutic lesions occur in the mouth: a bluish line, deposits of sphaecele on the tonsils (of great diagnostic importance according to some writers, but rare). The anaemia is more or less severe, and after reaching a certain degree may progress even if the cause is removed.

Cases are reported with symptoms of toxic polyneuritis, retrobulbar neuritis, retinal haemorrhages, and lessened resistance to infectious diseases. Further, local action on the skin and mucous membrane is frequent, more or less severe, according to individual susceptibility. These skin appearances are: roseola, swelling, erythema, and eczema; the patient complains of discomfort, sensation of dryness, especially of the uncovered parts of the body (face, neck, arms). The action is more noticeable on the mucous membrane: frequent conjunctivitis, blepharitis, and even keratitis. It is of importance practically because commercial benzois are always mixtures (petroleum, benzine, petrol, etc.).

DIAGNOSIS

When it is known that exposure to the action of benzol is in question, the headache, vertigo and distress (which often obliges the person to stop work) serve already as very important aids to diagnosis.

In the subacute and chronic forms the cutaneous and nasal haemorrhages, the meno- or metrorrhagia is women, the examination of the blood, the pink colour of the mucous membranes, with
absence of signs of cyanosis, are useful signs in the diagnosis of effects of benzene vapour and for differential diagnosis from nitro and amidodervatives.

Examination of the blood is useful: delay in coagulation and neutrophil leucopenia are of primary importance in diagnosis, but the trained medical man will not depend solely on these.

In cases with raised temperature the history should be carefully examined, because wrong diagnoses have been made from failure to consider or recognise the occupation of the sufferer.

**PROGNOSIS**

Prognosis must be cautious; recovery is possible with or without sequelae (often of a chronic nature). But severe and even slight cases with slow development have in general a fatal result. In these cases frequently haemorrhages can be found over large areas of the skin early in the course of the intoxication.

**DEMONSTRATION IN THE AIR**

More than 1 milligram of benzene per litre of air is necessary before the smell is distinctly perceived. Aspirate the air to be analysed through a wash bottle containing a mixture of sulphuric and nitric acid which fixes the vapour as a nitroderivative; extract with ether; add an excess of stannous chloride (the derivatives are converted into amino products); estimate the excess of stannous salts added by titrating with iodine. This method is said to detect a thousandth part of a milligram (Heim and Herbert). According to Ogier and Kohn-Abrest it is sufficient to make the air bubble through some cubic centimeters of fuming nitric acid, afterwards diluting with water to separate the nitro-benzene; neutralise with soda; extract by shaking with ether which removes the nitrobenzene, evaporate the ether off and weigh the residue. Use of white mice has also been suggested in workrooms, as they are very sensitive to percentages of benzol which have no effect on man.

**PROPHYLAXIS**

(a) **First aid** (see that article).

(b) **Manufacture of benzol.** — Supervision of the installation and processes and careful watching of the apparatus (prevention of escape of vapour).

Smear the cocks with glycerine which, being insoluble in benzol, ensures air tight joints.

When cleaning, repairing or emptying, etc. the reservoirs it is necessary to make sure that the apparatus is cold, that it is ventilated as fully as possible, that work is done under the supervision of a competent person who is made responsible, and that the workmen wear breathing apparatus. Experience has shown that even these precautions have sometimes not been sufficient.

The safest method would appear to be to let down a cage containing white mice into the receptacles and vats. If they become poisoned, cleaning with water and steam should be repeated before the workmen enter.

(c) **Contact with benzene.** — Generally speaking benzene and benzol are used in industry as a solvent and the solution is often applied to large surfaces (e.g. in waterproofing materials, painting, walls, ceilings, etc.). In such cases prophylaxis becomes very difficult, because the industrial processes are not finished until evaporation has taken place and the solvent has passed into the air.

The fundamental principle should be to catch the benzene vapour at the point of origin; but in most processes this solution of the problem meets with almost insurmountable difficulties, because the surfaces covered by benzol or solutions containing it are so large that no mechanical localised exhaust can be installed in such a way as to capture and remove the toxic vapour.

Further, cases are shown to be more frequent in cold weather because of defective ventilation then. Closed or warm workrooms favour evaporation of benzol and concentration of the fumes in the air. The action of other gases, such as carbon monoxide and carbon dioxide, which may be present at the same time, may aggravate the situation.

In cases where merely to instal mechanical ventilation is not sufficient, as it is necessary also to heat the incoming air — a matter it is difficult to insist on with small occupiers.

As a result of an enquiry made by the British Ministry of Labour into a number of fatal cases which had occurred in a factory in Edinburgh, it was found that a minimum of 2.1 parts and a maximum of 10.5 parts of benzene vapour per 10,000 parts air were present in the workroom in question. The ten machines could, it was calculated, give off 0.420 of a cubic metre of benzene vapour per minute in a room of 1,540 cubic meters capacity. Were the air renewed thirty times an hour, and the diffusion of the vapour uniform in the room (remembering that benzene va-
pour is heavier than air), the room would contain 0.065 per cent., i.e. 3.5 parts of benzene vapour per 10,000 parts of air. The same room if unventilated would contain, after an hour, 168 parts of benzene vapour per 10,000 parts of air. It was therefore necessary to solve the problem either by prohibiting the use of benzene or requiring good artificial ventilation of the kind adopted for the ventilation of doping rooms in which tetrahydroethane had given rise to serious cases of illness among the workers.

With this system of ventilation applied, the benzene vapour could be reduced from 28 parts per 10,000 to 5 parts, and the Home Office Regulations for india-rubber require that in workrooms where benzene is used as the solvent the air shall be changed thirty times an hour. Under these conditions very rarely can as much as 0.6 mg. of benzene vapour per litre be present. Lively discussion has ensued in different countries as to the practical possibility of effecting such a frequent renewal of the air without increasing the evaporation of benzol and without setting up draughts annoying to the workers. It has been suggested that 10 changes of air per hour is already ample and that the suggested new conditions of ventilation, the toxic vapour at their job is not excluded. Indeed fatal cases have been described in persons who had worked in well-ventilated rooms and with the windows open. Whether it is so or not must be left to the test of experience, hoping that it may not be absolutely necessary to demand "excessive" ventilation, which may be inapplicable in practice, but only a change of air such that the content of the air in each particular case shall not exceed 0.6 mg. of benzene vapour. Others consider that the ventilation should be such as to prevent a proportion of benzene vapour in the air of 1 part per 10,000 parts of air.

Protection of the skin of the fingers against contact with benzol during work is difficult, and up to the present no complete solution has been found.

Benzol should be kept, and the solution prepared, in places isolated from other premises (danger of explosion and fire). (See article "Petroleum").

As far as possible benzol should be replaced by toluol, xylok or their compounds, carbon tetrachloride, and even petroleum benzine (see these articles).

**INDIVIDUAL PRECAUTIONS**

Eliminate persons recognised to be specially susceptible (those suffering from heart disease, arteriosclerosis, alcoholics, neurotic subjects, young persons, especially girls). Periodic medical examination (blood examination, determination of the time of coagulation of the blood, prevention of infectious diseases, precautions before admission of convalescents, especially from infectious diseases) is a useful guide in vocational selection, and it permits of temporary or permanent suspension of subjects showing premonitory symptoms of benzene poisoning. Onset of epistaxis in a worker in contact with benzene (metrorrhagia outside the catamenial period in women) should be sufficient to warrant suspension from work of the persons in question.

**LEGISLATION**

Exclusion of children, women, and young persons from work exposing them to benzene vapour. (See articles "Poisonous Gases and Fumes" and "Nitro-Amine Derivatives").

**Children up to 15 years.**

*Italy.* Manufacture of carbon compounds and their derivatives, premises for the distillation of tar, for preparing solutions of rubber (india-rubber, ebonite, gutta-percha) and for applying them to substances to make them waterproof.

*Japan.* In workrooms in which toxic gases are given off.

*Poland (formerly Russia).* In rubber factories and chemical works.

*United States.* Manufacture of toxic dyes (Delaware).

**Children up to 16 years.**

*Argentina Republic.* (See below: women.)

*Belgium.* Tar distilleries: degreasing, dyeing, dry cleaning, and workrooms where naphtha or toxic substances are used; extinction of fat by benzol.

*Canada (Quebec).* Rubber and varnish works.

*France.* Manufacture and distillation (on a large scale) of petroleum spirit, tars, hydrocarbons; manufacture of plasters by means of hydrocarbons in the workrooms where the solvents are used.

*Greecce.* All factories in which toxic gases are given off.

*Spain.* Use of varnish with rubber as a basis; premises in which benzol vapour is given off; use of hydrocarbons in rubber works; manufacture of mustard plasters; degreasing of skins, cloth, and wool.

*United States.* In the manufacture of substances giving off toxic gases (Alabama, Arkansas, California, Connecticut, Kentucky, Maryland, New Jersey, Ohio, Oklahoma, Wisconsin): in the manipula-
tion of toxic substances giving off fumes and gases (New Jersey).

Young Persons up to 18 years of age.

France. In workrooms and dye houses in which toxic substances are used.

Women up to 18 years of age.

Greek. (See above.)

Women up to 21 years of age.

Germany. (See article “Nitro-Amino Derivatives.”) Prussia (see the Ministerial Decree of 18 December 1908 concerning labour conditions in the extraction and storage of benzene).

Spain, Italy. (See above.)

Exclusion of women altogether.

Argentine Republic. In the refining and distilling of hydrocarbons; in processes giving off benzol vapour; manufacture of varnishes, impermeable goods; distillation of tar compounds.

France. In the manufacture of the derivatives of benzol (see article “Nitro-Amino Derivatives”); manufacture of rubber and rubber goods where benzene fumes are given off; dye works, varnish works, painted tiles, substances to be coloured by means of benzene derivatives, etc.

Norway. Pregnant women only, where toxic vapours are given off.

Regulations.

Storage depot (see article “Petroleum” for details).

In gas works the benzol should be conveyed to the carburetter by a metal pipe of small diameter placed underground. The service cocks should be placed in such a position as will allow of the feeding and regulation of the carburetter without entering the depot.

Germany. (See article “Painting Industry (ships).”)

Great Britain. The Chemical Regulations require exhaust ventilation or every other means for preventing the escape of toxic vapour and heavy gases; breathing apparatus for those likely to be exposed in any place to toxic gases: compressed oxygen cylinders for first aid. (See article “Nitro-Amino Derivatives.”)

Compulsory Notification.

Great Britain. (See also article “Nitro-Amino Derivatives.”) Netherlands: list “A” of the Act of 1921; list “B” requires the notification of lesions of the skin and mucous membranes (bucal and nasal) occurring in persons engaged in refining tar derivatives and handling such substances. Duration of compensation: 7 days for lesions of the skin and mucous membranes, and 6 days for those of the eyes (cornea and conjunctivitis). Bavaria, Saxony, Switzerland (benzene did not exist in the list of 1916). New York: The very wide formula adopted by the legislature of Missouri (toxic gases, Ohio, and Massachusetts (“every indisposition or malady due to the occupation”) would cover notification of cases of benzene poisoning.

Recent experience would, however, make it desirable to notify cases of purpura haemorrhagica with profound anaemia, nervous symptoms and weakness with bleeding from the nose, gums and uterine, and to allow at least two months as the period for compensation.

Assimilation of benzene poisoning to accidents of work: Austria (cases of benzol poisoning “can” be regarded as accidents), Great Britain, Switzerland, Minnesota, New York, Ohio.

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Benzene Derivatives


Detailed review is not necessary here relative to the question of the composition and internal structure of the benzene molecule. It will suffice to say that the formation of new derivatives takes place by substitution in the hexagonal formula of benzene and of its homologues, of atoms of H and that, whatever may be the complication of these substitutions, the six original atoms of carbon of the ring remain unchanged.

Benzene has the formula C₆H₆; one of its homologues, toluene (C₆H₅CH₃) (see that article), is a methylbenzene, and another, the m-xylene C₆H₅(CH₃)₂ (see that article) is a dimethylbenzene.

If the substitution only affects a single atom of hydrogen, the substitute
may occupy any one of the six atoms; but if more than one atom is replaced, the isomers thus produced, whilst having the same number of atoms, have varying properties and a degree of toxicity which differs according to the position of the substitutes.

The disubstituted isomers may be either "ortho", "meta" or "para" derivatives; these terms are explained according to numbers given to the position in the ring, as follows: 1-2 = ortho; 1-3 = meta; 1-4 = para.

The number of isometric forms is greater when there are more than two substitutes, as is shown by the number of the angle: 1, 2, 3; 1, 2, 4; 1, 3, 5; etc. The number of isomers is still greater when one substitute differs from the other two.

In the benzene radical is united to an alkyl or to another radical, for example, C, H, CH, or C, H, CH, CH, CH, etc., one speaks of a lateral chain, and the benzene radical is then described as a nucleus.

Although there is no rule for judging the toxicity of isomers, the para position is, nevertheless, according to Fraenkel, more poisonous than the ortho position. However, according to the researches of Lewis, the meta position, for example for nitrauniline, is more toxic than the para. In the same way, for the nitrochlorobenzenes, the ortho isomer is more toxic than the meta and the para. But as regards phenylenediamine, experts do not agree, some considering that the para isomer is the more toxic and others the meta. The products obtained by substitution of an H atom of the ring are more toxic than those obtained by substitution of an H of a lateral chain (Hamilton).

If nitro groups take the place of H atoms of the ring, nitroderivatives of benzene and their homologues are obtained, which are dealt with in the article "Nitrobenzene".

If, on the other hand, the hydroxyl group (HO) is used, phenols are obtained (see that article); phenic acid or phenol is a hydroxybenzene; cresol is a hydroxytoluene; naphthol a hydroxy-naphthalene.

The introduction of the hydroxyl group makes naphthols (alpha, beta) more irritating than naphthalene. Any increase in the number of hydroxyls increases the toxicity of the product obtained. That is why, for example, trihydroxybenzene or pyrogallol is more toxic than monohydroxybenzene or phenol.

The introduction of the sulphonic group (SO, HO) into a derivative of benzene, weakens its toxicity; just as the same result often follows the introduction of a carboxyl group (CO OH). The introduction of an acetyl group (CO CH,) or a methyl or ethyl group gives a substitution product less poisonous than the original product.

This statement holds good when the substitution takes place in the lateral chain by the replacement of an H atom from an NH, group. But if the substitution takes place in the ring, then another product is obtained of a similar toxicity.

All aromatic compounds containing nitrogen are more toxic than those which do not contain nitrogen; but there is no fixed rule, increase in the toxicity of an isomer not being in proportion to the increase in the number of NO, groups.

The introduction of halogens into an aromatic compound does not cause any important changes, nor any definite increase in toxicity.

When chlorine or bromine has to be substituted for one of the hydrogen atoms of benzene or of its homologues, a catalyser (iron) must be added. In monohalogen compounds of benzene, the hydrogen atom only enters into reaction with great difficulty.

Chlorination is an operation which enables chlorine to be introduced into an organic molecule by substitution in a saturated compound, or by addition to a non-saturated compound. The halogen derivatives which are used in the modern dye industry are derived from the substitution of Cl for an H atom or for a hydroxyl in organic compounds.

Ferric chloride or pentachloride of antimony are active chlorinating agents for introducing chlorine into the aromatic nucleus. In the lateral chain, chlorination takes place without catalysers, by making chlorine act on the vapours of the hydrocarbon exposed to light, or by treating with cold chlorine the hydrocarbon very strongly illuminated by electric lamps.

When a halogen is substituted for the NH, group of the corresponding rings by an intermediary of their diazo compounds, some halogen derivatives are obtained.

Chlorobenzene or benzene monochlorate or chloride of phenyl (C, H, Cl) is obtained by making Cl pass into
benzene at 18-20° C, in the presence of iron (in the form of metal sheets) as a catalyst. The hydrochloric acid given off is condensed in stone towers sprinkled with water.

Chlorobenzene is a colourless liquid with a faint smell, which boils at 131-132° C, without decomposing.

It is regarded as the least toxic of the benzene derivatives which do not contain Cl. But, although the experiments of Mayer prove it to be less toxic than benzene, several serious cases of poisoning are known: ten cases were reported by Mohr in 1902, due to chlorobenzene and dinitrobenzene; in three cases chlorobenzene only was concerned; the workmen showed symptoms after drinking beer. Rambousek mentions a case of poisoning after contact lasting three weeks with this product, and four cases among workmen who had upset some of this substance on their clothing.

Lehmann's experiments with animals show that chlorobenzene has a stronger narcotic effect than benzene. An atmosphere containing 1-3 mg. per litre is tolerated by cats for several hours without injury; an atmosphere containing 3-5 mg. produces deep narcosis; and one with 11 mg. causes at the end of an hour uncertain gait, at the end of an hour and a half midriasis, violent muscular spasms, and tremor, and at the end of three hours respiration with the Cheyne-Stokes character. However, even at the end of seven hours' exposure to the poison, these symptoms do not get worse. An atmosphere containing 17 mg. per litre kills an animal at the end of seven hours, causing pulmonary haemorrhages; and an atmosphere with 37 mg. causes deep narcosis in half an hour to follow at the end of two hours, even if the animal is carried at once into the open air.

The symptoms observed among men are headache, vertigo, dyspnoea, cyanosis, and a formation of methaemoglobin. The lesions occur chiefly in the blood, urinary passages, and nervous system (peripheral and central).

Among the polyhalogen derivatives, the paradihalogens are solid: the ortho and meta isomers are liquid.

By nitration of monohalogen benzene, the ortho and para isomers are obtained exclusively and may be isolated from the mixture by crystallisation, the para isomer alone crystallising on cooling. As a rule the ortho isomer occurs in the liquid state. Nitration of chlorobenzene at ordinary temperature gives in the benzene solvents 70 per cent. of para and 30 per cent. of orthochloronitrobenzene. Taking integral chloronitrobenzene at a high temperature as starting point, metachloronitrobenzene can be prepared.

A mixture of ortho and paradichlorobenzene is more toxic than the monochlorobenzene, but it acts in a similar way.

From mother liquors containing paradichlorobenzene, a mixture can be easily separated by fractional distillation which boils at 175° C., due to the presence of 75 per cent. of ortho and 25 per cent. of paradichlorobenzene. This mixture is used as a solvent of resins and lacquers. No cases of poisoning have been reported in the course of its preparation.

In the same way as monochlorobenzene, the para product is used as a disinfectant for clothes and furs, and as such has given rise to accidents; a fatal case occurred in a chemical cleaning works in Germany in 1920, and another, moderately severe, affected a person living on a floor above a fur workshop where a product, known under the trade name of "Global", was used which had, as a base, paradichlorobenzene. This product has been recommended as a substitute for napththalene for the preservation of clothes and furs.

These mono-, di-, and trinitrochloro-compounds are very poisonous products which, according to Von JakSch, have caused and are causing more cases of poisoning than are recorded in the literature on the subject.

Paranitrochlorobenzene (C₈H₇ClNO₂) has caused cases of poisoning in the course of its reduction to paranitrochloranilide. According to Fischer and Sturmann, the ortho isomer is very volatile and, in consequence, very toxic. It causes among animals, symptoms of poisoning even in a dilution of 2-10 mg. per litre of air. It is more toxic than the para isomer, which is an intermediary product in the manufacture of sulphur blues, whilst the ortho is intermediary in the manufacture of anisidine.

During the preparation of nitrophenol, starting from nitrochlorobenzene, some cases of poisoning have been observed which have been attributed to this last product. Likewise it is blamed for nervous and psychic symptoms exhibited by a chemist and his fellow-workers who were employed in centrifuging nitrochlorobenzene.

The symptoms reported were headache, vertigo, more or less marked cyanosis, pains in the gastric, hepatic and splenic regions, optic neuritis, coma, collapse and cardiac paralysis.
Hunziker and Koechlin, of Basle, in 1922 reported a case of poisoning by paranitrochlorbenzene in a small boy who had swallowed some crystals of this substance picked up in the vicinity of a chemical works. Symptoms appeared an hour later; marked cyanosis, localised chiefly in the mouth and eyes; attacks of dyspnoea; pulse, 200; temperature normal; headache; fits of excitement; troubles of co-ordination; jaundice on the second day; nephritis on the following days; eosinophilia in the blood on the tenth day; recovery was very slow and took several months.

Generally these products can enter the body through the skin — a very important point in industrial practice — and by the inhalation of their fumes. Although these products are employed nowadays in the dye and explosive industries, the number of cases of poisoning is not very great, perhaps because the meta and para isomers are only slightly volatile.

In industry mixed poisonings are most frequent; they are notified under the vague name of anilism or poisoning by nitro- and amino-derivatives.

Thus, for example, in 1920, 17 cases of anilism were reported in two German factories, most of which had been caused by nitrochlorbenzene. The duration of these cases never exceeded five days on an average, except for one case. In Bavaria 10 cases of dermatitis and eczema caused by dinitrochlorbenzene and other aniline colours were reported.

Lehmann, Müller, Sturm, Dressler, and others who have studied these products experimentally, have shown that the inhalation of 0.05-0.08 mg. of ortho-nitrochlorbenzene per litre of air prolonged over three days and including a total of seventeen hours and a half, caused among cats characteristic phenomena and death. Sturm, in 1908, and Dressler, in 1910, investigated acute and chronic poisoning by vapours and vapourisation either of the product in question, or of "Tropsol".

According to these researches it would seem that the para isomer is a little less toxic than the ortho.

Bourquinet has described two cases of poisoning by nitrochlorbenzene which occurred in a Swiss explosive factory in 1919. But the number of cases of industrial poisoning by this product is not high; it was quite important during the war, on account of its use in the manufacture of explosives and where necessary precautions were not taken.

Dinitrochlorbenzene, C₆H₄Cl(NO₂)₂, which has been very little studied, is still more toxic than the mono. It is an irritant to the skin and to the mucous membranes and also causes digestive troubles (Lehmann). When used in the dye industry (sulphur blacks) it frequently causes dermatitis, which is characterised by itching of the skin confined chiefly to the elbow, the popliteal spaces, the interdigital spaces and the internal surface of the thighs. The skin is covered with small red points which become confluent and then change into vesicles and pustules.

The patient complains of a violent sensation of burning. It is well to note that these products take effect even through a layer of vaseline. Sometimes the dermatitis affects the face and eyelids.

General symptoms often appear from 8 to 24 hours after contact with the poison: headache, vertigo, vomiting, cyanosis, cramps, heart spasm, and ocular troubles. In serious cases, improvement is, very often, a premonitory sign of a fatal issue.

Dinitrochlorbenzene ("Parazol") has been studied by Macclure and Lussky (1920). When applied to the skin (of animals) it exercises an irritant effect, which shows as hyperaemia, followed by oedema and necrosis, depending on the length of the application (two hours). Oedema and redness may continue, even after the poison has been removed, lasting for about twenty-four hours. When applied to the human skin, parazol gave no reaction at the end of an hour, but hyperaemia appeared two hours after, accompanied by small vesicles. At the end of three hours and a half, pronounced itching occurred and later oedema.

The sublimated product, obtained by cooling the vapour of the hot crude product, is not as active as crude parazol; nor is its effect so great when it is mixed with lanoline.

Inhalation during three minutes (animals) of the vapour of parazol crude or melted, is not fatal.

Chloride of benzyle (C₆H₅Cl) is obtained by passing a current of chlorine into vapour of boiling toluene, exposed as much as possible to light, or by treating toluene, very strongly illuminated by electric lamps, with cold chlorine. This substance is toluene, with an atom of Cl substituted for an atom of H in the group CH₃.

Generally the simultaneous production of chloride of benzylidine and of phenylchloroform is unavoidable.

Chloride of benzyle is a liquid with a pungent smell, strongly lachrymatory, which boils at 176°C. It is used in the
preparation of green colours (Malachite green), and of benzoic acid.

According to the experimental work of Lehmann, exposure to about 1-2 mg. per litre of air for 30-60 minutes causes either at once or later on, serious effects or death; 0.4 to 0.6 mg. for 30-60 minutes either does not cause any symptoms or at least no serious symptoms; whilst 0.1-0.2 mg. per litre can be tolerated even for six hours' exposure.

The same author says that 0.2 mg. per litre causes pronounced irritation, and 0.5 mg. violent irritation; 0.9 and over may, after an inhalation of several hours, cause results sometimes fatal. Similar products, such as bromides of benzyl and xylene, the chloride and iodide of xylene, etc., are all lachrymatory gases. Bachfeld considers that the chloride of benzyle can cause dermatitis (eczema). Hamilton has reported a case of poisoning (see further on).

Chloride of benzylidene (C₆H₅.CH Cl.) is similar to the preceding, but with two atoms of Cl. These two products of the lateral chain are not so toxic as the chlor-toluenes, where the H of the ring is replaced by Cl (C₆H₅.CH Cl.).

Hamilton mentions a case of poisoning by a mixture of chlor-toluenes: chloride of benzyl and xylene. This was the case of a chemist employed for nine months in a dyeworks, who was exposed to the vapours in question, and had become very thin and presented a cyanosed coloration of the skin, with serious loss of strength, conjunctivitis, troubles of vision which became worse as the air of the place became charged with vapour of chloride of benzyl, pains in the hepatic region, and insomnia. It was not, however, possible to make an exhaustive examination of the patient.

Chloride of benzoyle (C₆H₅.CO Cl) is a liquid with a disagreeable odour which boils at 194° C.; it is strongly irritant and has up to the present been very little studied.

It originates from the action of pentachloride or oxychloride of phosphorus on benzoic acid or by the action of phosgene gas on benzene, in the presence of chloride of aluminium. Industrially it is prepared by making Cl act on benzaldehyde. It is used for introducing a benzyl group into a compound. Its irritant and violent action on the mucous membranes is due to its decomposition into hydrochloric acid and benzoic acid.

The other halogen derivatives, the bromides, iodides of benzene, such as benzene monobromate, moniodate, bromide of benzyle, and iodide of benzyle, have no practical importance in industry. Generally speaking, this applies to such lachrymatory gases as bromide of xylene and bromide of toluene.

As regards hygiene and legislation, the measures and instructions given in the articles "Nitro-Amino Derivatives," "Benzene," "Toluene," "Nitrobenzene," etc., are valid.

The Swiss legislation enumerates in the list of substances, injuries from which are compensated as accidents, the chloride and bromide of benzoyle, the nitrochlorate derivatives, the oxy-bromide and oxychloride of benzene; whilst other legislation class these substances under the general heading "Nitro-amino derivatives of benzene and homologues" (see that article).

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**Benzidine**

French: Benzidine (Paradiaminophényl).

— German: Benzidin. — Italian and Spanish: Benzidina.

**Properties**

Benzidine is represented by the formula

\[
\text{NH}_2\text{C}_6\text{H}_4\text{NH}_2\text{C}_6\text{H}_4\text{NH}_2\text{NH}_2\text{C}_6\text{H}_4\text{NH}_2\text{NH}_2\text{C}_6\text{H}_4\text{NH}_2 = \text{NH}_2
\]

— NH₂. It crystallises in the pure state in an aqueous solution in large colourless shining flakes, whose melting point is between 197.5° and 198° C. and boiling point 400-401° C. (at 740 mm. of Hg.).

It dissolves with difficulty in water (1 part in 244 parts at 17° C. and in 106.5 parts at 100°); it is comparatively soluble in ether (1 part in 45 parts); it dissolves readily in alcohol. It is not taken up by ordinary steam. As a commercial product it takes the form of a finely crystallised powder, of a shade passing from a light reddish-grey to white; it is slightly irritant to the nasal mucous membrane and possesses a bitter taste, similar to that of pepper. It melts at 123-124° C. and boils in the open between 380° and 450° C.

With oxidising bodies benzidine gives a series of very delicate colour reactions, which makes its examination quite an easy matter. In alcoholic solution it gives, with chloride of iron, a magnificently green colour, which soon passes off. A solution in sulhide of carbon, in chloroform or ether, gives with bromine water an intense blue colour tinged with green; with chlorine water it forms a red precipitate.

Ferrocyanide of potassium and bichromate of potassium give, in the most dilute solutions, a pale blue precipitate. The reaction used as a test for haemoglobin, with the formation of a blue or bluish-green product, is based (according to Adler) on oxidation of benzidine by oxy-
Benzened water in the presence of catal-
yzers. (For its use in the examination of
urine, see further on.)

Benzenized has a slightly alkaline reac-
tion and, like the other aromatic bases,
such, for example, as aniline, it forms
directly, on the addition of acid, crystalli-
sable salts which correspond to the for-
mula \(-\text{NH} - \text{HCl}\). In acid solution it
forms with nitric acid tetranitrate bodies
(tetranitro-derivatives), by the transforma-
tion of two amino groups \(-\text{NH}_2\) into
diazro groups \(-\text{N=N}-\).

Among the salts of benzenized the sul-
phate is almost insoluble, even in boiling
water and in alcohol; use can be made
of this fact to isolate benzenized. The di-
chlorhydrate which is more important from
the technical point of view is the following:
tolazine, which corresponds to toluidine, a ben-
zenized derivative, can be isolated and, like the other aromatic bases,
its homologues which have just been men-
tioned, and dichlorbenzidine, vice chlor-
benzine.

Among the homologues of benzenized,
the most important from the commercial
point of view are the following: tolidine,
which corresponds to toluidine, a ben-
zenized derivative, can be isolated and, like the other aromatic bases,
its homologues which have just been men-
tioned, and dichlorbenzidine, vice chlor-
benzine.

Benzenized was discovered in 1845 by
Zinin by making sulphuric acid react on
benzidine. Hoffmann, Fittig (1861),
and Schultz (1874) determined its composi-
tion in preparing dinitrodiphenyl by the
process of reduction.

Benzenized and its homologues have only
acquired a technical importance since the
development of synthetic congo dyes, for
they are very largely employed for mak-
ing direct dyes for cotton, which are em-
ployed without using mordants.

Since the preparation of congo red by
Boettcher in 1884, through the tetranitra-
tion of benzidine and combination with
naphthonic acid (acrid x naphthylamin-
sulphonic), there has been discovered a
whole series of cotton dyes which belong
to this group, the principal of which are
the following: the congo dyes, chrysamine,
diamine blue, diamine red, diamine black,
benzopurpurin, diaminide blue, and many others.

**Preparation and Use**

In consequence of its extensive use in the
manufacture of dyes, just referred to,
the industrial preparation of benzenized takes place on a large scale
exclusively in the coal-tar dye industry.

It is prepared by starting with hydrazo-
benzene \(\text{NH}_3\) \(\text{NH}_2\) \(\text{NO}_2\) \(\text{NO}_2\)
from which it is extracted easily by
the transposition of this product by an
acid solution.

Hydrazobenzene is prepared, starting
with nitrobenzene, by alkaline
reduction by means of soda lye and
zinc powder; for the rest the technique
is similar to that of aniline by
reduction in an acid solution (see that
article). Reduction by the electrolytic
method has not yet been applied in
industry. The apparatus used for the
reduction is composed of a receptacle
of sheet iron, fitted with a revolving
screw, a cooling coil, and a steam pipe:
the whole apparatus is generally
smaller than that used in the prepara-
tion of aniline. When making on a
small scale, the reduction is carried out in alcohonic solution; it can also be
conducted in an aqueous solution with
energetic stirring at boiling point.

Iron filings can be used instead of
zinc powder, as in the manufacture of
aniline, once the reduction is finished;
the contents are diluted with water
and the alcohol is separated by dis-
tillation. Then, after cooling the zinc
powder, which is not changed and is
contained in the crystallised hydrazo-
benzene, the residue, consisting of
oxhydrate of zinc, is passed through
metal gauze. The hydrazobenzene is
retained on the gauze and then isolated
in an almost pure state by washing.
Using this process of reduction, the
quantity of hydrazobenzene obtained is
relatively small; however, a fraction of
nitrobenzene, from about 4 to 5 per
cent., is changed into aniline (and, for
that matter, it is the same when the
process of acid reduction is used),
which is eliminated partly by combina-
ting with the alcohol and partly by
reuniting with the hydrazobenzene
during the operations which follow.
Further rectification is not necessary.

The second phase in the preparation
of benzenized, the transformation of
hydrazobenzene, is carried out by heat-
ing this product with hydrochloric
acid in closed receptacles, first to 55° C.
and then to boiling point. Thus is
obtained an impure solution of chlor-
hydrate of benzenized, with a small
residue of chlorhydrate of aniline.
After the addition of sulphuric acid or
sulphate of soda, the base is separated by
filtering the precipitate in the form of
sulphate. Where as the aniline
present in the solution takes the form of
a salt of a mineral acid (sulphate of
aniline or chlorhydrate of aniline),
the sulphate of benzenized, transformed by
means of a warm solution of soda or
of soda lye which precipitates it, is separated from the mother liquor by aspiration and washing; the aniline salt (sulphate of aniline or chlorhydrate of aniline) is in this manner entirely removed.

When sulphate of purified benzidine is not immediately put on the market in the form of a moist paste, as was formerly done, but is used in the manufacture of nitric dyes, it is heated in a dilute solution of soda or in soda lye. The solution is concentrated, filtered and cooled. The base liberated takes the form of shining colourless flakes. This product, which is already very pure, is again purified by distillation in vacuo at 300°-400° C. While warm and fluid it is run into iron vats, then it is crushed after cooling and solidification. The quantity of sulphate of benzidine obtained represents about 90 per cent. of the nitrobenzene employed.

Tolidine is prepared in the same way by reduction of ortho-nitrotoluene in an alkaline solution, and the transposition of orthohydrazotoluene is obtained by acting upon it with hydrochloric acid. Orthodianisidine is prepared in the same way, starting from ortho-nitroanisol, by reduction and transposition of hydroazoanisol. In the two cases the quantity obtained is small, amounting in the case of dianisidine to only 40-44 per cent. of the crude product used. In the case of the reduction of ortho-thiazolic anisol a very large quantity of the corresponding mono-amine is formed (0-anisidine).

Benzidine and its homologues are only manufactured in view of their use in the coal-tar dye industry, and that almost exclusively for the preparation of numerous nitric dyes used for dyeing cotton, some of which have been mentioned above.

Benzidine is also obtained, but on a much smaller scale, in the course of the manufacture of thiazolic colours (for the details, see article "Aniline"). The technique for the manufacture of nitric colours is as follows: dinitration of the base by means of nitrite of soda in acid solution and combination, in an alkaline medium, of the dinitrite formed with the appropriate compounds. The compounds employed are generally naphthal, naphthylamine, the meta phenylendiamine and its sulphonic acids.

Instead of the base itself, its salts are also sometimes submitted to dinitration, in particular the sulphate; and these are also used in the manufacture of some of the colour derivatives, of which the chief are the sulphonic acids which are prepared in the following way: the sulphate is heated with sulphuric acid to 170° to 210° C.; the purified mass is treated with a lye wash (an alkaline lye wash) and taken up by the acids. Like all sulphonic acids they are insoluble in alcohol and ether; they do not dissolve the lipoids, and are not poisonous.

Sources of Danger

The handling of benzidine and its homologues usually presents less danger than that of the mono-amines with a single nucleus, e.g. aniline and its homologues. Theoretically, according to the results of experiments on animals, the toxicity does not seem to be sensibly weaker; that can be explained by the less complete volatilisation of benzidine, especially by steam, and because it is less easily accompanied by impurities. The danger is much smaller when sulphates are used instead of the base.

1. During the making of benzidine and its homologues, the risks of injury are greater with the starting products (especially nitrobenzene or nitrotoluene) and with the aromatic mono-amines (aniline or toluidine) which form by secondary reaction, although in smaller quantity during their reduction than with the final products, the boiling point of which is high and which are not carried off by steam.

The danger of poisoning is especially great during the actual reduction or during the evaporation of benzidine, still containing as impurities the by-products mentioned, if these operations are carried out in apparatus which is not hermetically sealed.

2. During its use for the manufacture of nitric dyes, it is not always possible to avoid the liberation of dust while filling the receptacles for dissolving and denitrating with powdered benzidine (the sulphate of benzidine is usually used in the form of paste). Dust comes off chiefly when filling is done with a shovel. In the same way during the making of sulphonic acids, volatilisation of the free base may occur.

Toxic Action

It is generally agreed that benzidine and its homologues, by analogy with the other aromatic bases, enter the system, notably in the form of dust, not only by the respiratory passages and digestive organs, but also through the intact skin. Nevertheless sufficient evidence is not yet available to enable
it to be said which of these ways of entrance is the most important from the hygienic point of view; but it is thought that the principal path of entry is the respiratory apparatus. However, that many of these cannot be absorption by the skin during the handling of sulphate of benzidine.

The toxic effect and the final exit of the benzidine has only been ascertained by experiments on animals. According to the researches of Adler, which are, however, disputed by other experts (Klingenberge, Kuchenbecker), benzidine, like the other aromatic amines, is oxidised in the body and transformed into a diamino-dioxydiphenol, which is eliminated as such.

The urine is of a dark colour which seems to be due in part to derivatives of haemoglobin, among which are the bile pigments, and in part also to products of the transformation of benzidine.

According to experiments made upon animals (Adler) benzidine acts on the nervous system, on the blood, and on the metabolic exchanges. On the nervous system this action shows itself by fatigue, vomiting, and motor excitement, which with larger doses reaches paralysis; the fatal dose is lower than 0.2 grm. by mouth for dogs; it is higher for rabbits.

On the blood the action of benzidine shows itself by morphological changes in the red blood cells whose resistance is increased. Diminution occurs in the number of red cells; and sometimes methaemoglobinaemia with brown coloration of the blood. With rabbits pronounced haematuria is frequently observed. In acute poisoning cases the effect on metabolic exchanges is manifested by a serious glycosuria.

**SYMPTOMS**

Cases of acute poisoning by benzidine or its homologues have never been reported in human subjects, neither have injuries, acute or chronic, corresponding to toxic effects noted during experiments made on animals. From the point of view of industrial practice the toxicity of these products is, then, so slight, that it is not possible to draw a clinical picture of an acute case of poisoning in man. [The cases of poisoning reported by Hamilton, concerning two men who worked in a benzidine department, are not very clear and could have been slight forms of anilism.] Nevertheless, dust of benzidine and its homologues exercises a certain irritating action on the skin (eczemas: Bachfeld), and on the nasal mucous membranes, which is manifested, especially with dianisidine, by very violent sneezing. On the other hand, these products have, from the viewpoint of occupational pathology, a much greater importance as regards the onset of diseases of the bladder, which are met with among workmen manipulating benzidine and its homologues over several years. In the same way as aniline and other aromatic bases, these products cause haemorrhages and tumours of the bladder; papillomata and cancer (see articles "Aniline", "Naphthalylamine", "Tumours", "Occupational Diseases: Urogenital System").

Nassauer, who has himself observed quite a series of tumours of the bladder among workmen occupied in making benzidine, especially at the evaporation and distillation, is not of opinion that this affection is due to benzidine itself, but to aniline vapours which are set free, although in small quantities, during its manufacture. However, the observation of this author, as well as that of other experts, scarcely leave any doubt that benzidine and also its homologues are a cause of tumours (Schwerin).

As is the case with all the other aromatic bases, it seems that the inhalation of the smallest quantities in the form of dust or fumes is sufficient to cause, when prolonged for years, the onset of diseases of the bladder.

**HYGIENE**

In the same way as for all the other aromatic amines, the preparation of benzidine, and especially the precautionary measures of reduction of the raw product and of distillation, must be carried out in closed receptacles, especially provided with an exhaust system either general or local. The separation and washing of the by-products, and particularly their evaporation, must be done in covered receptacles fitted with an exhaust system. Emptying distilled benzidine into open tanks or vats, not supplied with an exhaust system, must be strictly prohibited. Similarly, the greatest precautions must be taken while emptying the pipes of the distilling apparatus, in order to prevent the inhalation of vapours. The same precautions must be taken during sulphonation. The liberation of dust must be prevented while the products are being crushed and packed (see article "Naphthaline"). To the manufacture of nitric colours care must be taken to avoid the formation of dust and splashings which fall on
the floor while the tanks for dissolving and dinitrating are being filled.

**Legislation**

See also the articles "Aniline" and "Nitrobenzene".

In Germany regulations are in force in Prussia and Bavaria controlling the starting and carrying on of businesses for making and recovering nitro- and amino-aromatic compounds. The regulations are concerned with the construction and technical equipment of the works, with changing rooms, baths, lavatories, and dining rooms; with the exclusion of women and children; with medical examination on engagement and periodically every four weeks. Injuries caused by benzidine are compensated in Switzerland and in all countries which have included in the list of industrial diseases the nitro and amino derivatives of benzene and its homologues.

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**Bismuth**


Bismuth is found in nature as native bismuth in argentiferous strata in Saxony, Bohemia, France, and Bolivia; it occurs in the form of lamellar or granular masses, and sometimes in the form of rhombohedral crystals of a reddish or silver-white colour containing traces of sulphur, arsenic, tellurium and selenium. Its density is from 9.7 to 9.8, and its hardness from 2 to 2.5. It is also found as: the sulphide, bismuthine, in Bolivia, Sweden, Australia, and Saxony; the oxide, bismuthoxhre or bismutile, in Saxony, Bohemia, and France; the carbonate, bismuthoferrite and bismuthite; or in combination with lead.

**Industrial Processes**

Metallic bismuth (symbol, Bi) is of a greyish white colour and is easily crystallised; its melting point is 267 to 269° C., and its atomic weight 208. It almost always contains arsenic, sulphur, iron, nickel, cobalt, copper, antimony, and silver.

It is obtained from the native metal by simple melting, but this process has now been given up because the extraction is incomplete, and it has been replaced by processes similar to those used for antimony (see that article).

The extraction of bismuth from minerals may be carried out by dry or wet processes. In the first the ore is roasted and smelted with coke and a fluxing agent which is often iron. The reduction process is not infrequently combined with a precipitating process. By the wet method bismuth is precipitated from hydrochloric solutions by means of iron. The bismuth so obtained is always impure and has to be purified by melting with 10 per cent. its weight of potassium or sodium nitrate. The sulphur, arsenic and foreign metals become oxidised and form a dross which can be easily removed. Although purified it still contains in small quantities the substances mentioned above.

Bismuth is chiefly used for the preparation of various metallic alloys of low melting point, which are used particularly in the making of safety valves, printing type, stereotyping, and in making illustration plates.

The salts of bismuth are of no importance from the view-point of industrial hygiene.

It must be recalled furthermore that, in association with nickel and cobalt, bismuth occurs with arsenic and sulphur in the ores obtained from the mines of Schneeberg (see article "Cobalt").

**Toxic Effect**

No figures are available relating to the risk of poisoning for workmen who manipulate bismuth or its compounds. The possibility of poisoning is provided against when ores containing it are dealt with; but in that case impurities, such as lead, arsenic, copper, or antimony, may play the more important part in the origin of any trouble.

Among persons who have absorbed large doses of bismuth, the appearance of a blue line has been noted, exactly similar to that caused by lead (Oliver). After swallowing bismuth, Bresgen reported redness and inflammation of the buccal mucous membrane, then a bluish-black coloration of the borders of the gums, the tip and sides of the tongue, uvula and palate. The coloration of the mucosa of the cheeks corresponds with that of the teeth; it appears usually after disappearance of
the inflammation and may be attributed to the formation of sulphide of bismuth. Dubinsky is of opinion that this inflammation resembles that caused by chronic mercurial poisoning. It is helpful to bear in mind that bismuth is eliminated not merely by the urine, but also by the salivary glands. A study of the blood reactions in bismuthism was made by Sabrazes and Grailly in 1923 and compared with the reactions in lead poisoning.

Soluble salts of bismuth are poisonous. The neutral nitrate which decomposes into the sub-nitric and acid nitrate may give rise to serious accidents; the latter exercises a corrosive action. The sub-nitrate often contains as impurities, lead, chlorine, and arsenic.

Administration, over a long period, of small doses of the oxide or acid nitrate of bismuth produces in animals wasting and a peculiar cutaneous eruption (Meyer).

Cases of bismuth dermatitis of industrial origin are unknown. On the other hand, the literature on the subject records the case of a German chemist who, in 1907, while separating bismuth from a solution of chloride of bismuth in hydrochloric acid, was poisoned by the arseniuretted hydrogen which was evolved.

**DETECTION**

Inorganic liquid: among the recognised methods proposed, the best is that of Aubry, which is characteristic. There are, however, certain possibilities of error which must be carefully avoided. The method need not be given here as it lies within the province of the chemist and the clinician.

**LEGISLATION**

No special legislation.

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**Bleaching**


**TECHNICAL DATA**

The bleaching of different products such as fibres (animal and vegetable), materials, oils, and fats consists, in effect, of the removal of darker parts or rendering the same invisible, so that the whole becomes as far as possible uniform in tint or whiteness.

Bleaching is carried out with a view to immediate use or as a preliminary to printing with colours.

Substantially, all bleaching processes consist of oxidation or reduction by the employment of certain physical or chemical processes.

**Vegetable and Animal Bleaching**

Vegetable fibres are bleached by other methods than animal fibres: for the first (cotton, artificial silk, flax, jute), the process consists of conbustion of the colouring parts by oxidation; for the second (wool and silk), of reduction of the darker tint, while retaining the uncleared parts.

Bleaching may be (1) natural or grass bleaching or (2) chemical.

**Grass or Natural Bleaching**

The material is first boiled in soap and water (bleaching of cotton and linen). It is then spread out on a field of grass in a wet state to undergo oxidation by means of the oxygen in the air. This continues for some weeks, and the article is afterwards rinsed in chlorine water.

This process may be accelerated by pouring chlorine water over the article from time to time while it is lying on the grass.

**Chemical or Workshop Bleaching by Various Processes**

(a) Impregnating the fibre while boiling with 2 per cent. natron lye and chlorinating with natron hypochlorite (cotton bleaching).

(b) Boiling with or without lime, treatment with soda solution and chloride of lime, and afterwards with dilute sulphuric acid.

(c) Diluted chlorine lye solution (chlorine lye is an article of commerce) at 38°-42° C. (linen bleaching).

(d) Diluted chloride of lime solution (1-2 per cent.) and formaldehyde solution in weak solution (½ per cent.; jute bleaching).

(e) Special dilute hydroxosulphite compound containing Na₂S₃O₆ in a 1½ per cent. solution as found in the commercial preparation "Decroline, Burmol, Rongalite"); this is a reducing process.

(f) Diluted sulphur natron solution, chlorine, hydrochloric acid and sulphites (artificial silk bleaching).
(g) Electrolytic chlorine bleaching — the bleaching fluid electrolytically prepared.

(h) Sulphurous acid steaming — burning sulphur (wool bleaching).

(i) Electric bleaching, in effect, ozone action.

(j) Hydrogen superoxide solution, suitable for all fibres.

Special Methods for the Bleaching of Different Fibres

Wool bleaching.— The bleaching of wool is preceded by the removal of grease, for which various chemical grease-removing appliances are employed, among others the commercial preparation "Hexoran", which contains carbon tetrachloride. In the Netherlands certain workers in a woollen blanket factory contracted serious stomach complaints through the employment of this preparation.

For the purpose of bleaching, sulphur powder is burned in a brazier in a chamber, for the formation of SO₃ or sulphur vapour is released from cylinders, also producing SO₂.

The hanging and removal of woolen blankets, in spite of the ventilation of the chamber, gives rise from time to time to difficulties in breathing.

In dyeing wool fibre, this is previously lightly bleached by the reducing preparation Na₂S₂O₄ at about 70° C.

The hydrosulphite compound is brought into the factory in the form of powder, under the name of Burmol. Another much used compound is Decroline, which is a zinc hydro-sulphite formaldehyde compound.

Cotton bleaching.— The process here is as follows.

The woven pieces are sewn together, laid over gas-flames (generator-gas), and the finish removed by washing; they are then treated in the impregna
ing machine with 2 per cent. natron lye at boiling heat. Thence they go to the so-called revolving trucks or revolving boilers, in which they are boiled under pressure with a strong lye solution. The distribution of the cotton sliding down from above on the floor of the revolving boiler, carried out by boys in an atmosphere of hot steam, is unhealthy work. Clothing becomes wet through, which gives rise to colds and their consequences.

The boiling is followed by chlorinating (generally so-called, by means of natron hypochlorite, with subsequent chlorination, with natron sulphite in closed apparatus.

Alternatively the goods are boiled with or without lime; caustic soda solution and chloride of lime solution are afterwards employed, and the lime is then removed by the addition of a diluted sulphur acid solution. Finally, the material is rinsed several times with water and wrung dry, processes which are carried out mechanically.

The caustic soda is brought into the factory in a molten state in closed boxes, is broken into pieces with hammers, and afterwards opened, so that the danger of getting splinters of caustic soda in the eye is avoided. The natron hypochlorite in strong solution is introduced in closed earthen vessels, drawn out of them by an iron pipe into reservoirs, and from these by tubes into the cellars, where the chlorine basins stand. This involves no touching with the hands.

Sulphuric acid, 66° B., is extracted from the tank-wagons under pressure by cast-iron tubes internally covered with cement.

Linen bleaching.— This process, both for threads and woven pieces, is carried out with commercial chlorine lye (natron hypochlorite and watery solution) at 38°-42° C. in diluted solution.

Artificial silk bleaching.— After the viscose process artificial silk is successively treated with sulphur natron solution, water, chlorine, hypochloric acid water, and antichlor natron sulphate. Until recently the rigid artificial silk was hung on staves and shifted with the hand, while the vessels of solution were poured over it one after the other. The hot sulphur natron solution gave rise in a number of cases to loss of epidermis from the fingers; the strong hydrochloric acid fumes from the buckets used in filling the hypochloric acid bath produced an inclination to cough, and catarrhal symptoms in the upper air passages. The hand-bleaching process has been replaced by a mechanical process, by which the staves of artificial silk are propelled through a bath and rinsed with various solutions.

Jute bleaching.— Jute fibre for sacks is not bleached, in order to prevent weakening. For colouring fibres the rigid jute is hung in a vessel containing diluted chloride of lime and formaldehyde solution, and is then placed in a centrifugal machine and rinsed.

Flour bleaching.— For flour bleaching sulphur dioxide is used; for starch bleaching hydrogen peroxide; for potato flour sulphur dioxide. Sugar is bleached
by means of animal charcoal (see article "Sugar") in filter presses furnished with a mixture of sawdust and other materials (coke, pumice stone, etc.; this process even succeeds when carried out without heating); another method consists in adding to the final clearing syrup a little ultramarine blue or methyl violet, or better still, by means of indanthrene. In certain factories, in order to effect immediate bleaching the last boiling is decolorised with a bleacher or hydrosulphite.

**Bleaching of fats and oils.**— Oil is heated to 60°-80° C., and white or grey "Florida bleaching earth" is added to it in a copper. This is a fine powder with a greasy feeling to the touch, and producing little dust, analysing as follows: silicic acid, aluminium, magnesium, iron, and calcium oxide. The bleaching depends on the colloidal character; colouring parts are taken up by adhesion. "Lucidol", a commercial product with a peroxide of benzoyl basis, is also used. In linseed oil bleaching an alkaline lye is used in solution, with danger from spluttering when pouring a warm (40° C.) alcoholic solution into the oil. A solution (see article "Bleaching") of indanthrene, with danger from spluttering when pouring a warm (40° C.) alcoholic solution into the oil.

Bleaching of skins and feathers.— This is carried out by means of hydrogen peroxide. In the case of hair, this is first washed with a warm 40 per cent. ammonia solution, rinsed, and then treated with H₂O₂. Feathers are first cleansed from grease and then bleached.

**Bleaching of ivory and horn.**— These are successively placed in diluted potassium permanganate solution after rinsing in water, in 10 per cent. oxalic acid solution, and finally in hot, slaked lime.

**Bleaching of calfskin.**— After cleaning with soap and water, the material is placed in a hydrogen peroxide bath at 34° C.

**Bleaching of skins and furs.**— For sheepskins bleaching with H₂O₂ and diluted sulphuric acid is preceded by treatment with alum, soda and soap solution (see article "Fur Industry").

**Leather bleaching.**— This is carried out with sulphurous acid after removal of grease with benzine.

**Glue bleaching.**— Glue is bleached in a copper at 105° C. with "Decroline" (basic zinc formaldehyde hydrosulphite).

**Bleaching of paper pulp.**— Lime with a pressure of 0.3 atmospheres is used for this. If soda or caustic soda be used, a concentration of about 0.1-0.2 per cent. is necessary. This type of bleaching is also carried out in successive stages, but two operations are substituted for four or five. In this process it is essential to eliminate not only the natural impurities of the fibre, but also the grease, sweat, and dressing in the rags.

Bleaching in this industry is easier than in the textile industry, and 0.2 grm. of chlorine per litre suffice in the washing trough. The action of increased pressure renders the fibres less resistant. Dressing is now eliminated by using malt, which does not affect the fibres; dilute sulphuric acid may also be applied. The use of emulsions such as oils, fats, soaps, favours the access of chemical reagents to the heart of the fibres and the elimination of material contaminating the rags.

Chlorine may be replaced by hydrogen peroxide. Permanganate of potassium and perborate may also be utilised, but this process is less common than the former.

**Straw bleaching.**— Wet straw is kept for hours in boiling water, then treated with sulphuric acid vapour, rinsed with water and dried. Hydrogen peroxide is also employed, or a combination of bisulphite, H₂O₂ and natron hydrosulphite; also chloride of lime in water — saturated solution.

**Bleaching of cane.**— For this purpose also chloride of lime and sulphur dioxide vapour are used; never sulphuric acid.

**Coconut fibre bleaching.**— The coconut fibre is placed in a diluted solution of chloride of lime and sulphuric acid, in iron or cement vessels in the open, or in SO₂ vapour of burning sulphur in an enclosed space.

**Wax bleaching.**— As in bleaching of oils and fats, this can be done with aluminium-magnesium hydrosilicate or with natron superoxide, etc.

**Shellac bleaching.**— Shellac may be bleached, among other methods, by pouring a warm (40° C.) alcoholic solution into fresh chloride water, stirring at the same time, sifting the separated lac, washing with distilled water and drying.

**Bleaching of bath sponges.**— Exposure successively to cold diluted potassium permanganate solution, potassium chlorate solution and hydrochloric acid in wooden tubs.
Sources of Danger

Even with the adoption of the most adequate precautions workers may be exposed to the harmful action of the products mentioned above.

It is chiefly a question of the irritating or toxic action of gases and fumes and localised caustic action of alkaline solutions. Often the products used give off fumes disagreeable for the workers and the neighbourhood. The risk of pollution of rivers and the subsoil by waste water must also be borne in mind.

The use of bleaching powders is very widespread; it is even common to see workers, cooks, general servants, etc., using them for cleaning their hands, washing dishes, clothes, etc.

Besides this local or general action must be recalled such further conditions of work as high temperature, humidity, steam from the vats and boilers, wet flooring, necessity for alternate work in and out of doors involving exposure to sudden changes of temperature. Amongst the products liable to cause harm may also be mentioned compounds of chrome hydrofluoric acid, etc.

In a quite modern bleaching powder factory Leymann found that 17.8 per cent. of the men employed and exposed to chlorine fumes suffered from respiratory troubles, whilst only 8.8 per cent. presented similar troubles in the other departments.

The use of a liquid for bleaching hats, and containing sulphur t alc, glue and formaldehyde had caused amongst the workers a persistent irritation, a burning sensation and skin eruption (see also article "Formic Aldehyde").

In a bleaching powder factory the use of manganese peroxide caused, according to Couper (1837), two serious and three slight cases of poisoning by manganese.

The increasing use of chlorine gas cylinders for bleaching flour had given rise to six cases of chlorine poisoning in Great Britain in 1922. Bridge visited several plants of this type and reports that the occupiers, happily aware of the danger, have posted up notice of the precautions required. As far as possible such apparatus should be kept outside the workrooms, as in the case of freezing plant. Good ventilation should be provided and the requisite precautions taken to meet all risk, either due to the production of a crack in one of the cylinders containing the gas, or connected with transport or neutralisation. The workers entrusted with the work

ing of this plant should be provided with respiratory apparatus and trained in its use.

The same expert recalls the necessity found for bestowing particular attention on elimination of fumes coming from sulphur stoves in bleaching and laundry establishments. Owing to the prevalent fashion for white, such sulphur stoves have been in constant use. The process, which consists of burning raw sulphur inside the stove, is extremely primitive; but when the stoves are isolated from the surrounding buildings, can be opened at both ends and cleaned by drenching with water before the workers are obliged to enter them, they present no cause for complaint. On the other hand, when such stoves are situated in the centre of the establishment, itself the centre of a dense mass of buildings and surrounded by workers' dwellings, the solution of the problem presents great difficulty. Employers should arrange for as rapid and complete elimination of the fumes as possible. However, if such elimination be effected either mechanically or by other means with liberation of the fumes at the height of the dwellings a new danger arises. The best solution would probably be the transference of the stoves far from such centres, but before the opportunity arises for putting this into effect, better methods of ventilation can and ought to be applied in co-operation with the local authorities so as to ensure dispersion of the fumes in the most practical manner.

Hygiene

In establishments for bleaching by chlorine and hypochlorites the flooring of the workrooms and courts should be impermeable; there should be installed in the workrooms a very effective system of ventilation, all vats, troughs and such apparatus should be constructed of masonry coated with cement and carefully treated with a bituminous cement; before opening the various chambers the chlorine gas should be forced into a hermetically sealed apparatus where it is passed over milk of lime, and any gas remaining after absorption should be made to pass into a high chimney with a powerful draught. The vats should be covered with wide hoods serving to draw off the fumes and steam towards the factory chimney. Stoves should be constructed of incombustible material, and each workroom should have at hand a carboy of ammonia to counteract the effect of the chlorine in case of sudden liberation of this gas.
Where bleaching of linen and woollen materials is effected by sulphur dioxide, the general hygienic measures provided for the establishments above referred to should be applied. Sulphur stoves should be of incombustible material and should be provided with a high door near the top which can be opened at the end of each operation, simultaneously with the other doors, in order to create a draught which will expel the sulphur dioxide. It is preferable to provide the sulphur stoves with ventilators which drive the gas into a very high chimney. When the dioxide is used in solution the work should be effected in a sealed apparatus.

Preventive measures against fire are called for, likewise precautionary measures in regard to liquid or solid residues, by prohibiting dispersion of these on public ground or in sewers. The workers must be protected against the action of toxic and corrosive substances by provision of gloves, suitable working clothes and respiratory apparatus.

**Legislation**

The employment of young persons under 16 is forbidden in Belgium in operations pertaining to the bleaching of woollen and silk yarn or materials by means of sulphur dioxide in workrooms where this gas is liberated; likewise during bleaching of yarns or materials made of flax, hemp, or cotton by chlorine and hypochlorites in places where chlorine is liberated. Young persons under 18 are excluded in France in operations connected with the bleaching of straw, cloth, or paper when chlorine and sulphur dioxide fumes are given off. In Spain under similar conditions young boys under 16 and girls under 21 are excluded from employment. For the Netherlands, see Labour Order, 1920, section 8 (e); section 33, subsection 20; annex, section 35; Safety Order, section 343 (b). In Great Britain Lord Brougham in 1860 drew the attention of the House of Lords to evidence on the subject given before the House of Commons Committee, and, in consequence, bleaching and dyeing processes were brought within the Factory Acts. The law relating thereto was later amended and consolidated, bleaching powder factories are now made subject to the Regulations applying to the chemical industries of 1922 (see article "Chemical Trades").

**Bleaching Powder**

(Chloride of Lime, Calcium Hypochlorite)


**Properties**

Solid chloride of lime is a white powdery substance, hygroscopic, smelling of chlorine or hypochlorous acid, and having a tart taste. The formula for chloride of lime has not been determined; according to certain authorities its essential component is $\text{Ca(OCl)}_2$, that to say, a mixed salt consisting of hydrochloric and hypochlorous acids. Other authorities believe it to correspond to a mixture of calcium chloride and hypochlorite of lime ($\text{Ca(OCl)}_2 + \text{CaCl}_2$). Partially soluble in water to which it imparts decolorising properties, it dissolves similarly in hydrochloric and nitric acid with effervescence. The chlorine element in the chloride of lime is easily replaced by acid and even by the carbonic acid gas of the air which explains its decolorising and disinfecting properties.

Bleaching powder is sold in wooden barrels lined with paper and having the bottom of the barrel plastered. In order to avoid explosions they must not be quite closed. The chloride generally contains 35 to 40 per cent. by weight of active chlorine (the theoretical maximum being 48.7 per cent.), which corresponds to 323.127° Gay-Lussac. It ought to be kept away from the light and kept cool to avoid decomposition. As a matter of fact, chloride of lime absorbs carbon dioxide and moisture from the air giving off chlorine. The substance decomposes and liquifies. The rapidity and completeness of the reaction depend upon the temperature and degree of humidity. crystallised chloride of lime contains 39 per cent. to 40 per cent. of chlorine; liquid chloride of lime, a limpid fluid smelling of chlorine, becoming turbid and changing readily on contact with air, contains 45 gm. of active chlorine per litre.

**Industrial Processes**

Solid chloride of lime is obtained by passing chlorine over slaked lime which has been carefully and slowly ground and sieved. This is carried out in completely enclosed apparatus, as in the Schultess apparatus. Lime of first quality shaken in a revolving drum is slaked, then falls in powder form into the external envelope of the apparatus in which it is collected.

The lime is conveyed to a hopper placed in the upper part of a chamber recalling that for the manufacture of
sulphuric acid. It is lined with vitrified bricks, or more frequently with lead. The inside lining is painted with a coat of tar-asphalt. The lime is placed in these chambers in layers 4 to 5 cm. thick on small horizontal shelves usually made of lava or lead arranged in stages. Where there are no shelves the lime is spread out on the floor of the chamber to a depth of about 20 cm. by means of a very long poker. The work is unpleasant, but not dangerous.

The chlorine is introduced by means of “lutes” into the upper part. Each chamber is provided with doors of iron or wood protected by iron and having peep-holes (glass panes) let in for observing the state of the reaction. If the chlorine contains carbon dioxide, the absorption of which by the lime gives off heat, recourse is had to cooling in order to prevent decomposition of the chloride of lime into chlorate and chloride of calcium. With this in view, leaden pipes, through which cold water circulates, traverse the mass of lime. The process of manufacture is continuous with at least three or four chambers in communication above, one of which is always either out of action or undergoing recharging.

The chlorine is introduced slowly until it ceases to be absorbed. It passes from one chamber to another, driving out the air in front of it. Although the lime readily absorbs the chlorine, it is necessary to distribute the powdered lime mechanically in the chambers in order to avoid escape of the gas into the atmosphere.

In the Gastner revolving furnace, which consists of a steel cylinder lined with vitrified brick, the manufacture is continuous, the chlorine and the lime circulating in reverse directions. Hasenclever’s apparatus, which diminishes the risk of inhalation of chlorine, consists of a structure containing horizontal iron tubes placed one below the other. Automatic devices distribute the lime. The mechanism can only function continuously with the gas rich in nitrogen and oxygen yielded by the Deacon process. With chlorine concentrated as it is in the Weldon process the reaction requires to be stopped from time to time, so as to prevent a too energetic reaction.

When the process is completed the chloride is received in wagons placed under the chambers, the bleach being pushed down by a shovel into the evacuation shoots. There are, however, automatic processes of removal. As stated above, the chlorine which has not been fixed is, at the moment the chamber is put out of action, carried by a current of air into another chamber so that the work of emptying can be done as far as possible without risk of absorption of gas.

The chloride of lime is then passed through metal sieves before it is packed to prevent formation of solid lumps. The dangerous processes of transport and packing are now done in closed automatic apparatus provided with means for the removal of dust.

Liquid chloride of lime (bleach liquor) is made by replacing the solid slaked lime by milk of lime, or more simply by dissolving lime in chlorine water and subsequent filtration, or again by electrolysis of chloride of lime and allowing the chlorine to combine with the chloride of lime into chlorate and giving off heat, recourse is had to cooling in order to prevent decomposition of the calcium hydrate formed as in the case of the hypochlorites of sodium and potassium.

Crystallised chloride of lime is obtained by saturating milk of lime with electrolytic chlorine, filtering and evaporating under reduced pressure.

**USES**

Chloride of lime is used on a large scale in different industries as a decoloriser and disinfectant. Generally it replaces chlorine in numerous applications because it can be easily carried: 1 kg. of chloride of lime freshly prepared gives off about 110 litres of chlorine.

As a decoloriser it is used in the bleaching of paper pulp, textile threads, etc.; as a mordant in printing tissues; in dyeing (preliminary treatment of the vegetable fibres — cotton, hemp, linen, jute, etc.); and for cleaning hands soiled by organic colouring matters. It is used as a disinfectant in industrial and town hygiene (tanneries, e.g. before any manipulation of foreign hides: Order of the Chancellor of the German Empire, dated 18 April 1891); in the manufacture of many organic compounds (chloroform, etc.), and in the purification of pure acetylene, etc. The irritating and caustic action of chloride of lime is due both to its content in free chlorine and its alkalinity.

**DANGERS**

In the course of manufacture,—The workers employed in the manufacture of chloride of lime are less exposed to occupational risks than would be supposed.

Danger to health occurs when the lime is pounded and slaked without taking precautions; from the chlorine especially in the leaden chambers.
when the lime is being shovelled at the same time that the chlorine is coming in, when insufficiently ventilated chambers are entered, or when emptying and packing are done without precautions. The risk is the greater the more concentrated the chlorine (chlorine produced by the Weldon process is more concentrated than by the Deacon process.) Lead poisoning has also to be considered than by the Deacon process).

Lead poisoning has also to be avoided by substituting hypochlorite of soda for chloride of lime as it has the same decolorising properties. At the same time that the chlorine is coming in, when the lime is being shovelled at the chambers. In packing there may be danger of explosion.

In the course of its use.— See above under "Uses".

STATISTICS

According to Leymann (1906), 1,941 workers employed in the manufacture of chloride of lime and caustic potash in German factories showed, during the period 1891-1904, the following morbidity per 100 persons: 2.3 for nervous diseases; 17.8 for respiratory; 12 for diseases of the digestive tract; 8.9 for infectious diseases; 11.3 for external injuries; 11.1 for diseases of the locomotor system; 8.1 for dermatosis; and 1.3 for organs of the special senses.

SYMPTOMS

Chloride of lime has a similar action to caustic alkalis, although less severe, and it has, further, a specific action on the sweat glands. Handling it or using solutions of the substance causes the eyes (lachrymation, conjunctivitis, etc.) and the respiratory tract (perforation of the septum of the nose, cough, asthma and sometimes bronchitis, etc.).

HYGIENE

The manufacture of chloride of lime, the object of which is to utilise chlorine in excess in the factory, requires that the chambers contain as little chlorine as possible when they are being emptied. The chambers should be in series and communicate one with another to secure a complete absorption of chlorine. The last one should not smell of the gas. All the chambers in series must be impermeable. Removal of the chloride of lime should be done mechanically and not by hand. Generally automatic mechanical methods, of which several kinds have already been proposed and applied, should be aimed at.

For cleaning the hands hypochlorite of soda should be used although it removes the colour less rapidly and does not remove completely methyl green, but it has none of the disadvantages of chloride of lime. According to Floret (1915), the substitute proposed by Greve (6.3 of hypochlorite of soda, 5 of sodium chloride, 1.5 of caustic soda to 100 of water) removes acid colours very well, but irritates the skin, makes the nails become brittle and fall out, and does not remove basic colours.

LEGISLATION

The work of adult women is forbidden in the manufacture of chloride of lime factories in Argentina and the Netherlands; employment of children under 16 years in Belgium (factories for the manufacture of dry chloride of lime and of the substance in solution); and under 18 years of age (in the manufacture) in the Netherlands.

In Great Britain the manufacture comes under the Chemical Regulations of 11 June 1922, section 20 of which reads:

No person shall enter a chamber for the purpose of withdrawing the charge of bleaching powder unless and until—

(i) the chamber is efficiently ventilated, and

(ii) the air in the chamber has been tested and found to contain not more than 2.25 grains of free chlorine gas per cubic foot.

A register containing details of all such texts shall be kept in a form approved by the Chief Inspector of Factories.

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The lesions set up by the substance are included in the list of diseases scheduled under the Workmen's Compensation Act (1906) in Great Britain.

In Switzerland, similarly, chloride of lime is included in the list of substances injury from which comes within the compensation law.

The Netherlands require notification of skin affections (dermatitis, eczema), ulceration of the mucous membrane of the mouth in persons employed in the packing of chloride of lime.

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Blood and Industrial Poisonings


The utilisation or liberation of poisonous products during trade processes presents special dangers to the blood. This "liquid tissue", as a matter of fact, penetrates every organ of the body, and comes into the closest contact with the atmosphere of the place where the work is carried on, through the mechanism of respiratory exchange. It can rapidly convey the poison with which it may be charged throughout the system, and more particularly to certain secretory or excretory organs where they may accumulate.

Poisons may simply pass through the blood without causing specific and peculiar lesions, or they may produce in it inorganic changes which reduce, as a preliminary effect, its function as a conveyer of oxygen and energy. It is essentially this last class that will be dealt with.

Morphological changes in the blood, which are easily recognised, like mass research work, are of value in proportion as they enable lesions to be early recognised. With this object the simplest processes are the best. Moreover, haematological methods have been studied these last few years as few others have, and are particularly designed for the conduct of periodical examinations into the state of health of workers.

Industrial hygiene in practice requires as rapid an examination as possible of workers in trades in which there are dangers of poisoning in order to determine the existence or non-existence of any sign, however small, of the action of poisons, so that aggravation may be prevented and the necessary prophylactic measures instituted.

In industrial life no one can escape from the influence of occupation, whatever it may be; but it is the duty of science to improve the methods for detecting any injurious effects brought on by the industrial life at a stage when recovery may be possible, or, at least, when no serious effect on the capacity for work or the duration of life has been incurred. As regards industrial diseases, prevention is far better, is easier, and is less costly than cure.

GENERAL REMARKS ON INDUSTRIAL POISONS

There is no doubt that, as concerns their action, the poisons are subject to the law of d'Arndt-Schulz, i.e. in quite small doses, below a certain strength, they act as excitors of new formation rather than as poisons. This is so with lead, arsenic, and phosphorus, very small quantities of which produce increased activity of the haemopoietic organs and increase the number of red cells (Meyer-Gottlieb). With a large dose and prolonged exposure, on the contrary, they cause anaemia and cachexia. Ammonia and sulphurous anhydride are considered by workers — and apparently with some justification — as tonics necessary to the system, and more particularly recognisably effective as prophylactic and therapeutic agents against colds, catarrhs, and tuberculosis. There always exists in the body a whole series of metals (besides iron, manganese, copper, zinc, phosphorus) which do not cause the least ill-effect.

Anyone who is not familiar with the proportions of metals normally present in human and animal organs is liable to make serious mistakes in chemico-legal analyses.

Knowledge of the action of metals is still incomplete, especially as regards the threshold of the poisonous dose for various organs and, more especially, for the kidneys. So there is no ground for surprise if, more often than not, it is not known in what form they pass into the blood and are deposited in the tissues. It is probable that they do not generally appear in the system in a completely dissolved state, but in the colloidal state, in combination with the albumens or acids (in the form of a salt of a fatty acid or of phosphoric acid). Neither is it surprising that they impregnate the bone marrow, so as to lead to the formation of new blood, and that they produce there toxic effects. But beyond what takes place in the case of lead and iron, nothing is known.

The influence of metallic and other poison on the structure of the blood plasma, as well as upon its physico-chemical properties, has been little studied up to the present. However, in the case of poisoning by lead and bismuth it is accepted that a displacement of the fractions of albumen towards the side of greater dispersion occurs, as well as an increase in fibrino-globulin, just as in infectious diseases (Kobert). V. Jaeksch has drawn attention to the analogy between acute poisonings and infectious diseases; and, although the mechanism of this action is quite unexplained, it is known chiefly from the work of the Danish Institute of Serology (Madsen) that small poisoning processes, that free haemoglobin becomes changed in the liver into globulin,
and that salts of manganese cause a very strong formation of antibodies.

It is probable that the influence brought to bear on the structure of the plasma does not occur without strong reactions, for changes of activity in the blood ferments may be looked for in consequence of modification in the dispersion of the albumens (see also "the activation of prothrombins" by protein bodies according to Weinhard). The foregoing ideas open extensive perspectives in the study of industrial poisons in the blood. In connection with this phenomenon must be noted changes in the ultra-filtrability of serum after mercurlal treatment (" Novasulur ").

A classification of blood poisons must of necessity have arbitrary limits. Of course the toxic effect — for instance, the haemolysis due to a single and special poison — need not be limited to a single process, and, in the same way, the fate of the haemoglobin can not be by a single and same poison need not always be the same. This is not surprising, considering the secrecy which is connected with most of the delicate processes which occur in the cellular laboratories of the animal body. Generous limits must be fixed to the evidence of observations as encountered in daily practice.

A. — RED BLOOD CELLS

I. HAEMOLYTIC POISONS WITH METHAEMOGLOBINAEAMIA AND HAEMATINAEMIA

This class includes all the poisons which have a destructive action on the structure of the envelope of the red cell followed by haemolysis. It is probable that this destruction is caused essentially by a reaction with the lipoids of the supporting substance of the cell stroma (the solubility of poisons in lipoids: Bechhold). Morphologically the condition is often indicated by the appearance of the so-called "internal haemoglobinemic bodies" (corpuscles intemnnes hemoglobi- biniques) of Ehrlich and Lindenthal, small spherical bodies of haemoglobin which are found in the interior of the red cells, and by the shadows of red cells described by Ponfick. Most of these poisons not only cause the discharge of haemoglobin from the stroma of the red cells, but a transformation of oxyhaemoglobin into methaemoglobin, that is to say, into a stable combination of haemoglobin with oxygen of such a kind that the haemoglobin, being firmly fixed, ceases to be available for the respiratory purposes of the cellular elements. Ehrlich, some time back, considered that these "internal haemoglobinemic bodies" constituted methaemoglobin. The blood, in this case, takes a dark venous colour, sometimes brown and blackish; there is cyanosis of the lips and extremities, deep coloration of the blood, which when bled is almost brown, and brown urination. Legge reports that, in practice, the blood in poisoning by aniline black is always of a chocolate colour with cyanosis.

Most of these particular poisons are met with in the chemical industry: aniline, nitro- and amino-derivatives of the aromatic and aliphatic series (e.g. nitrobenzene and, more particularly, dinitrobenzene, trinitrobenzene, trinitrotoluene and aniline), phenyl-hydrazine, pyrogallol, pyridine, picric acid, hydroquinone, nitrite of amyl, hydroxylamine, nitrous gas, chloride of lime, more rarely chloride of potassium, and chloric acid. With hydroxylamine there is, in consequence of oxidation, hydroxylamic acid at the same time as the formation of ematine (Kunkel). With nitrous gas, local action on the lungs, setting up oedema, and on the central nervous system is most important.

Benzene itself, by prolonged action of strong doses, causes the same effects. The female sexual organs are especially the seat of such lesions, chiefly at the time of menstruation.

Exact determination of the presence of methaemoglobin is made in the first place by spectroscopic examination of a very concentrated solution of blood (1:30), neutral or alkaline, which shows in the orange (from 634 to 602 μ ) a broad typical band. The other bands, which appear in a greater dilution and by the transformation of neutral methaemoglobin into alkaline methaemoglobin, and produce modifications characteristic of their composition, must be determined by the aid of the spectroscopic table of W. J. Dilling. It should be particularly noted that only when 40 per cent. of the oxygen is transformed into methaemoglobin do the bands appear and do clinical signs of poisoning become evident. Death occurs when 75 per cent. of the oxyhaemoglobin is transformed into methaemoglobin. It is evident that during this examination any oxyhaemoglobin which is present will always show itself by characteristic bands in D and E.

In the living the bands of methaemoglobin can be recognised in the orange by examining, with transmitted light, the external ear intensely illuminated as Rost, Franz, and Heise have strongly recommended. Methaemoglobin acts in relation to reducing agents, such as sulphide of ammonium, in the same way as oxyhaemoglobin does, and con-
sequently bands of reduced haemoglobin appear (see below).

O. Schumm was the first to establish the production of haematin with or without methaemoglobin in numerous cases of poisoning, caused by cyanides, dinitrobenzene, acetic acid, and chloride of potash, but not by lead and its compounds. Haematin is the pigment of blood; it contains iron, but is free from albumen, of which it is the first product of disintegration. As Schottmuller has recommended, it is advisable to proceed first to the spectroscopic examination of serum which, more often than urine, and even than blood solutions, contains methaemoglobin and haematin. This is shown by a band in the orange red (615 or 627 μμμ) to the right of the red band of haemoglobin and by two small bands in the yellow and green. Treated with sulphide of ammonium the bands change into those of haemochromogen (550 and 525 μμμ), whilst methaemoglobin becomes reduced into haemoglobin without oxygen, distinguished by a large dark band at the site of the two bands of oxyhaemoglobin at 560 μμμ.

Naturally there will be found in the serum oxyhaemoglobin, methaemoglobin, and bilirubin, but, according to Schumm, bilirubin, the pigment of jaundice, is almost always associated with oxyhaemoglobin and not with haematin, so that difficulties of diagnosis are rare. According to the observations of Schottmuller, there is found in haematinæma a coloration of the skin passing from yellow to brown, resembling slightly the jaundice coloration. The shades of coloration of the skin in poison, unfortunately, only have been slightly studied up to the present from the clinical point of view, although they may not be without their practical value.

From the anatomical and pathological points of view, this group of blood poisons causes very serious lesions of the organs and especially fatty degeneration of the liver and renal cells, sometimes even of the muscular fibres of the heart. There also occurs a formation of pigment and an accumulation of iron in the liver, kidneys, and bone marrow. The urinary canaliculi are completely filled with an accumulation of red cells, to such an extent that the clinical picture of oliguria and anuria is present. That may also be produced without blocking the canaliculi, in consequence of serious lesions of the renal parenchyma. The pronounced hyperaemia of the organs must also be noted, showing the existence of lesions of the capillary walls in consequence of which cutaneous haemorrhage or violent metorrhagia are produced, as, for example, in chronic poisoning by benzene, pyrogallol, and aniline. If the system recovers from the poisoning, a process of regeneration in the bone marrow takes places rapidly. All the blood cells which indicate such regeneration are then found: normoblasts, polychromat, and basophilic erythroblasts.

From the biochemical point of view, facts recently acquired on poisoning by nitrobenzene and aniline are of great interest, for they have shown that, until the definite elimination of sulphoconjugates and glucuronic acids takes place, intermediate products, such as phenylhydrazine and chinonine, complete the change into methaemoglobin by activation of oxygen in the processes of both reduction and oxidation (Heubner and Rhoden; Engel).

Besides this, a blood picture of strong degeneration may occur, without any sign of regeneration, such as polycytoysis, anisocytosis, micro- and macrocytosis, a picture which resembles that of pernicious anaemia. Depending on the state of the bone marrow, whether bone marrow or lymphoid tissue predominates, the picture obtained will be that of either regeneration or degeneration. In poisoning by benzene, according to Zanger, there occur, above all, leucopenia and thrombocytopenia in consequence of degenerative processes in the marrow. According to this author, the nuclei are in a state of pycnosis, easily stained, with preservation of protoplasmic structure.

In poisoning by aniline, Helm, Agasse-Lafont, and Feil have quite recently (1926) reported the presence in the blood, although rare, of red cells with very fine basophilic granules, seen in a third of the cases examined, with predominance among aniline workers.

**Acute Haemolysis by Arseniuretted Hydrogen and Organic Volatile Arseno-Derivatives**

Although it rarely happens, some poisons such as arsениuretted hydrogen and organic arsenical derivatives, the chemical composition of which has not up to the present been sufficiently investigated, may explain the occurrence of industrial processes of acute haemolysis. According to the amount of arsениuretted hydrogen inspired, the haemolysis will vary in intensity, and the
clinical manifestations which follow will vary, from the slightest blood changes which only appear at the end of 8 to 24 hours on blood in urine, but the serious sequelae, up to the most acute manifestations with destruction of red cells, which occurs in a few hours or even less, and reduces the percentage of haemoglobin in the blood to fatal limits (about 15 per cent.).

Even when danger of serious collapse is passed, there remains, as regards the kidneys, danger from anuria and uraemia in consequence of the urinary canaliculi in the kidneys becoming blocked by the debris from the red cells. Early detection can be carried out in an excellent manner by means of the simple micro-chemical methods which Erwin Becher has introduced into medical practice and only requires a little blood.

It was an accepted fact in days gone by that in poisoning by arsenuiuretted hydrogen there occurred a pure haemolysis with haemoglobininaemia and pure haemoglobinuria. G. Joachimoglu has recently established the fact that the formation of methaemoglobin also occurs in vitro and in the frog. In general many of the cases the determination can only be made in the serum (see below). It must not, however, be forgotten that spectroscopic examination succeeds only with a content of 40 per cent. of methaemoglobin.

Quite recently an occupational disease ("Gulf disease") was observed among the fishermen of a German port, a disease which, according to the latest researches, was not due to arsenuiuretted hydrogen but to organic arsenical compounds, which after prolonged inhalation during work have a similar action. These cases were characterised by haemoglobinuria and methaemoglobinuria (L. Lewin), with violent muscular pains and stiffening of the whole body. It was considered within the range of high probability that a micro-organism (for example, Penicillium breviculae) could cause, during the high temperature of summer, by processes of reduction of the mud of the port which contained arsenic, the liberation of organic arsenical combinations. Arsenic was present in waste water from a cellulose factory making use of pyrites, the waste water from which was discharged into the port (C. Lentz). It is interesting to know that, according to Lewin, methaemoglobinuria alone was found spectroscopically in the patients and not methaemoglobininaemia (see article "Arseniuretted Hydrogen").

From the viewpoint of the practice of industrial hygiene, it is interesting to note that, according to Zangger, poisonous combinations of arsenuiuretted hydrogen and nitrous vapours may be produced, for metals are often arsenical.

It is evident that the poisons under consideration may have a twofold seat of action. In the first place the circulating blood, where the poison directly attacks the mature red cells. At the same time action also occurs on the haemopoietic centres in the red marrow where, however, the attack is apparently a secondary one. As a matter of fact, debris of erythrocytes are found in the circulation, and it often takes some time before signs of blood regeneration appear.

According to the interesting experimental researches of Rous, Peyton, and G. O. Broun, destruction of red cells may occur as the result of violent muscular effort, especially if it occurs after a long rest. Broun is of opinion that in normal conditions a state of equilibrium is set up in which the destruction of the red cells acts as a regenerating stimulus to the bone marrow, which immediately forms new elements to replace the old ones.

These facts enable numerous forms of stubborn anaemia wherein athletic activity is a definite help to be classified in the same group. There is no doubt that this activity may accelerate the elimination of numerous poisons, e.g. lead in particular. From the point of view of industrial hygiene the development of sports for the working classes is to be recommended. Schmidt rightly estimates that physical training, rationally indulged in, is often much better and more beneficial than costly balneological treatment.

It is probable that the reticulo-endothelial mechanism of the liver and spleen plays a special part in the destruction of red cells, as it is in these cells that an increase and accumulation of the poison occur, and later it is there that phagocytosis of the debris of the red cells takes place.

The reticulo-endothelial system is stimulated in lead poisoning. This fact is proved by extensive development of the connective tissue in cultures of tissues in the presence of animal plasma, as well as by recent research carried on in Biondi's laboratories.

The reticulo-endothelial system is also stimulated, although to a less degree, in mercurial poisoning. The large macrophages of the spleen in rabbits suffering from lead poisoning engulf mature red cells, but not, it
seems, red cells which are not yet mature. The reticulo-endothelial system, thus stimulated, fills a haemopoietic function, of which material expression is found in myeloid metaplasia and in the appearance of cellular elements (Bianchini).

Very great scientific interest is afforded by the recent experimental researches made by Madsen (Copenhagen) and his pupils, in particular by Reymanns, who have shown that during haemolysis the liberated haemoglobin is probably transformed in the liver into fibrinogen and later into globulin. This increase of fibrinogen is not only caused by haemolytic poisons of bacterial origin, such as staphylo- ysin and diphtheritoxin, but also by chemical poisons, such as pyrodine and pyrogallol, so that it can be spoken of as a general law. Probably a defensive arrangement of the body is set up, more particularly of the liver, the action of which in the face of bacterial damage is sufficiently well known, whilst it is still obscure for chemical poisons. It may be that defence against metallic globular poisons lies in the envelopment and putting out of circuit of material exchanges, in so far as no destruction or transformation into a non-toxic form occurs.

By processes of disintegration, haemoglobin is separated into an albuminoid part, globine, and into a part containing iron, haematin.

This latter subsequently loses its iron and becomes changed into haematoxid and haematoporphyrin which, by passing through unknown intermediate forms, becomes bilirubin, which is reduced in turn to urobilin in the intestines and reabsorbed in this state, only to be oxidised in bilirubin once more in the healthy liver, while in a diseased liver the urobilin passes as such into the blood and into the urine. This same process of separation of urobilin occurs when the liver, in course of haemolysis, is flooded with haemoglobin or haematin. This is why urobiliniauria and even urobilinogenuria (a more advanced degree of reduction) represent a symptom of great value for detecting anomalies of haemoglobin metabolism and functional disturbances of the liver.

II. Haemolytic Poisons without Methaemoglobinæmia and without Haematinæmia (e.g. Lead)

(a) Modifications of Blood Formula

Things are different with such a blood poison as lead, which is very important and very common in daily life. Here the new blood formation after the inhalation of fine dust or vapour follows so rapidly the first onset of the poisoning caused by the metal that it may be attributed to a previous attack on the cells of the bone marrow, with karyokinetic excitation. However, according to the researches of Schmidt, the invasion of the blood by new polychromatophile cells and cells with basophilic granules appears when it can no longer be a question of a diminution of haemoglobin. That has been established in the case of animals, as well as in the case of man; and Schmidt has even seen the appearance of elements of blood regeneration among women employed at the work of decorating articles by means of transfers after only five days and without there having been any signs of previous anaemia. Schnitter has reported among white lead workers, often after only two days' work, a proportion of 100 basophilic granular cells per million. The conditions here are quite analogous to those caused by inorganic iron, which, according to Abderhalden, does not act directly on the structure of haemoglobin, but through a haemopoietic action by stimulating the bone marrow.

Further, according to Schmidt, in the development of lead poisoning there are two methods of attack upon the circulatory apparatus: at the centre of the reticulo-endothelial apparatus and of the marrow.

While, at an early stage, the action on the former is of greater importance, destruction of red cells in the blood stream, continued for a long time, and concomitant damage of the haemopoietic centres cause great diminution in the number of red cells and even sideropenia of the haemoglobin as themselves, to such an extent that the colorimetric index falls below 1. These lesions are probably explained by the fact that lead, as well as most of the poisonous metals, is not found in the circulation in a state of complete solution, but in a fine colloidal state as carbonate, phosphate, or salt of a fatty acid. In this form it is of course fixed in the erythrocytes, and slowly exercises its destructive action in the circulation, by which the reticulo-endothelial apparatus, as in the case of aromatic blood poisons, terminates the process. But at the same time the poison is introduced with the blood stream into the bone marrow, where, in consequence of the diminution of the speed of the circulation, it accumulates and affects the mother haemopoietic
cells. The haemolysing action of lead seems, according to recent researches of American authors, to be due to a change in the elasticity of the red cell in consequence of the formation of phosphate of lead and acid phosphates.

According to the researches of Biondi, not only does lead incite phagocytic activity, but it also exerts a complex stimulus, which gives to the reticulo-endothelial system a haemopoietic function and perhaps directs it also towards the formation of fibroblasts—which may explain the kidney and hepatic lesions of lead poisoning.

(b) Formation of the Granular Material

The observations of Schmidt indicate that the first manifestation of the toxic action of lead takes place on the nucleus of the normoblasts of the bone marrow; after that, or perhaps before, an elimination of poly chromatophile red cells appears as the first sign in the blood. The old conception of a pure degenerative state (Grawitz-Pappenheim), in consequence of destruction of the protoplasm of the red cells, has practically been abandoned, while the theory of W. Schilling, Rauch, and Michaelis of a degeneration of the young polychromatophile red cells lacks support of the facts.

This is how Schmidt explains the process of the formation of granules. The structure of the nucleus breaks up; derivatives from the nuclear substance pass out of the membrane (karyosecretions) and mingle together, part as very fine elements detectable by staining with basic colours (polychromasy), and part as elements in a coarser state known under the name of "basophilic granules". Smears of blood from a guinea-pig poisoned by lead, examined by the method of Kreibich, show all forms of granulation and lesions of the nucleus, protuberances on the nuclear membrane, and intermediate forms between the granulations and the nucleus. With the ultramicroscope can be seen varieties of the particles up to the finest polychromatic granules, so that according to Schmidt there is no longer any doubt as to the genesis of the formation of these elements. The rapid action of lead is due to the stimulus which it exerts on the nuclei of the mother cells of the marrow. After precipitate regeneration, sooner or later a slowing down of the regeneration may occur. But a condition may be established in which the nucleus becomes so accustomed to lead that the blood formula resembles morphologically that of the normal.

In fact, there can be no doubt that a certain amount of "salting" occurs among many lead workers.

According to the researches of Bianchini, punctuate red cells will sometimes be the only expression of an apparent reduction in the granules of basophilic substance which is usually spread uniformly over the whole element, following an autolysis of rapid evolution. In this case the appearance of punctuate red cells would be considered as an artificial phenomenon. The process which, so to speak, transforms the basophilic substance into granules might, under special conditions, also take place in the blood stream. Thus it can be understood why, starting from basophilic substance, the stage of the punctuate red cell through the polychromatophile can be reached.

The alterations in the circulating blood, especially the polychromatophile red cells and those with basophilic granules of new formation, and finally the consequent anaemia, are factors resulting from stimulation or regeneration in the red marrow, which can cause, by flooding the blood with new cells, a clinical picture comparable to that of anaemia. Quite a number of cases occur where, with a normal strength in haemoglobin and a normal number of red cells, a great artefactual of cells with granules have been noticed, as occurs in favourable cases. Evidently, it is a question here of a special reaction and a particular form of anaemia, and it is quite incorrect to regard the granules simply as a manifestation of anaemia. Simple forms of anaemia are not so often removed from these changes as is poisoning by lead.

Chlorosis is not characterised by the appearance of basophilia, not even when serious cases show a certain number of red cells with coarse and even with fine granules. The same thing may be said of posthaemorrhagic anaemias, of those caused by the above-mentioned poisons, and infectious diseases.

According to Schmidt, in lead poisoning a specific condition occurs, due to changes in the cells of the marrow and their nuclei. This nuclear state is not characteristic of other secondary anaemias in which only an indirect stimulation of the marrow is produced.

Estimations of blood lesions can be made by different methods of staining, depending on the object in view. Double stains, e.g. Giemsa and May-Grunwald, are quite unsuitable, for the red colours conceal part of the
nucleus, a fact upon which Schnitter has already insisted. In the opinion of Schmidt, the methods of staining most to be recommended are as follows:

(1) Staining with borax methylene blue (Manson’s method).

(2) Staining with the azure blue 11 of Giemsa modified by Schmidt-Koch (not to be compared with the double staining of Giemsa).

(3) Staining by Schwarz’s method (modification of the method of Manson).

(4) Staining by toluidine blue by the method of K. B. Lehmann.

These four methods (see further on for the technical part) cause a slight staining of the red cells, against which foundation the basophilic granules stand out much better. Deep staining with too concentrated solutions, as well as double stains, conceals the delicate granules. Schwarz has eliminated the defects from the various means of staining by Manson’s alkaline solution by keeping separate the methylene blue and the alkali (see further on). By his research in collaboration with E. W. Koch, Schmidt has increased the duration of the staining with azure blue 11 of Giemsa from ten seconds to two minutes (Schmidt-Koch method), in order to show up polychromasia in conjunction with granules.

The recent work of E. W. Koch shows the expediency of taking into consideration, in the course of a health examination of workers, the polychromatic elements as described by Schoenfeld, especially since advantage accrues from detecting the first signs of lead absorption industrially. In fact, if, after having found a normal blood, one suddenly detects the presence of numerous polychromatophile red cells, it can be ascribed to absorption of lead during work, if there is no question of other causes of injury, as, for example, haemorrhages. But polychromatophilia in this case only constitutes, as does basophilia in minor intensity, a danger signal or warning, and nothing more.

(c) The Blood Formula and Diagnosis of Lead Poisoning

With regard to workers in lead industries it is necessary from the start to make a choice among the men exposed to the risk (Carozzi), in order to be sure that the blood changes are not due to other causes, such as malaria, tuberculosis, carcinoma, haemorrhages, or poor nutrition. If comparison with the normal or anaemic blood is desired, a limit should be fixed to start from, so that blood examinations which are found positive may be accepted with greater confidence. A careful count of red cells with basophilic granules has shown that their limit should be fixed at 100 per million of normal red cells. But naturally the certainty of the results increases with an increase of this limit, Trautmann fixing it at 300 and Schnitter at 500 per million. These counts, however, call for withdrawal from unhealthy work.

Schmidt constantly recalls, and does so rightly, as much from a humanitarian as from a prophylactic point of view, that it is much better to stress too much the occupational origin of a case than too little. With indefinite subjective symptoms, when the doctor has to decide between shamming, hypochromadriasis, or occupational disease, the decision should incline — according to Schmidt — in favour of an occupational origin if repeated examinations show in the blood a count of 100. In these conditions a diagnosis of “lead poisoning” is not strictly justified, but “in dubio pro aegroto” — in case of doubt find for the patient. This conception is justified by the statistics of Schmidt and other experts. By way of example, it is fitting to quote here the tables of Schmidt (1907), of Trautmann (1909) and of Schnitter (1919):

<table>
<thead>
<tr>
<th>Limiting count</th>
<th>110 workers with no industrial contact with lead</th>
<th>546 workers with industrial contact with lead</th>
<th>15 cases of lead poisoning confirmed clinically</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above 100 cells with basophilic granules per million</td>
<td>Percentage</td>
<td>Percentage</td>
<td>Percentage</td>
</tr>
<tr>
<td>Up to 100</td>
<td>1.8</td>
<td>9.2</td>
<td>100</td>
</tr>
<tr>
<td>No cells with granules</td>
<td>85.5</td>
<td>72.9</td>
<td>—</td>
</tr>
</tbody>
</table>

TABLE 1 (SCHMIDT)
For cases of poisoning well marked from the clinical point of view, A. Sellers also gives a count of 100 per cent. positive results, and so does Koelsch.

Beyond doubt the count in many cases shows a parallelism between the blood changes and the degree of lead absorption and the damage done. Determination of the risk caused by an industrial installation is of great importance, a point upon which Carozzi has insisted when speaking of the kind of control to exert. For example, the industries which give most positive results are those where there is most dust (Schmidt), which demonstrates the correctness of Legge's conception of the importance of lead dust. This is why persons occupied in the transfer department of the pottery industry show counts which are definitely and clearly high when compared with those in other industries (especially in the polygraphic industry), and why women show great differences compared with men. There are in consequence possibilities of appreciable differentiation, which fact is supported by quite a rich literature (see following tables, Sellers, etc.). That applies not only when diverse industries are compared, but also when different departments of the same factory are compared, when the percentage of the distribution of workers who show positive results, as well as when the value of the results obtained is compared.

The proof is supported by some statistics supplied by P. Schmidt:

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Number of cases examined</th>
<th>Positive results (above 100 per million)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Painters; house painters</td>
<td>78</td>
<td>15.4</td>
<td></td>
</tr>
<tr>
<td>Typesfounders; founders</td>
<td>95</td>
<td>32.6</td>
<td></td>
</tr>
<tr>
<td>Tinners</td>
<td>32</td>
<td>9.4</td>
<td></td>
</tr>
<tr>
<td>Engravers of music</td>
<td>44</td>
<td>9.0</td>
<td></td>
</tr>
<tr>
<td>Compositors</td>
<td>70</td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>Engravers of printing type</td>
<td>27</td>
<td>3.7</td>
<td></td>
</tr>
</tbody>
</table>

And by Arthur Sellers (1921):

<table>
<thead>
<tr>
<th>Departments of an accumulator factory</th>
<th>Percentage of positive results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formation</td>
<td>25</td>
</tr>
<tr>
<td>Mechanical casting</td>
<td>27</td>
</tr>
<tr>
<td>Burning</td>
<td>50</td>
</tr>
<tr>
<td>Fasting</td>
<td>62</td>
</tr>
<tr>
<td>Casting by hand</td>
<td>70</td>
</tr>
<tr>
<td>Filling in plates</td>
<td>75</td>
</tr>
<tr>
<td>Melting</td>
<td>76</td>
</tr>
<tr>
<td>Warehouse (dust)</td>
<td>80</td>
</tr>
</tbody>
</table>

There are no other operations which show in such a certain and simple manner the risk of danger from lead poisoning. One can understand that objections are raised from many quarters to such a numerical determination of defects in the hygienic arrangements of factories. But, in the opinion of Schmidt, there is no further doubt that the blood formula can be of very great use for determining the danger risk and the hygienic standard of workshops.

The examination of the blood naturally calls for thoroughly successful preparation of the blood smears. The red cells should be isolated one from another, and not be piled together as occurs in bad preparations. The technique for spreading the films is as follows (Gilbert process):

1. Prick so as to obtain a good drop of blood from the pulp of the finger or the lobule of the ear without having to exert any pressure.

2. Collect the drop upon the narrow edge of a well-cleaned slide.
(3) While the slide is held obliquely at 45°, place the edge carrying the drop of blood upon the surface of a second slide which has been well cleaned and slightly warmed.

(4) Wait for the drop to spread out uniformly on the slide along the width of that edge.

(5) Then effect the spreading out by extending the smear.

Only too often, out of a number of smears prepared by doctors who are not experts, there is a large percentage of absolutely useless ones. It is in this way that the numerous negative results recorded in lead poisoning can be explained, quite independently of differences in staining and expert opinion (Schmidt).

It must once more be emphasised that, even under the above-mentioned conditions, the limits of count, fixed at 100-300 and 500 per million, are only probable counts; but they are sufficiently accurate from the prophylactic point of view. Still it need not be a question of exclusion from work when dealing with the lowest figures. If, however, an examination carried out on the whole personnel of a factory shows thousands of red cells with granules per million of red cells, the value of this examination will obviously be much increased.

It is known by experience that the blood formula in lead poisoning may exhibit variations, in that basophilia and polychromatophilia may be present or may disappear. The explanation lies in the fact that the marrow, like all other glands, especially in conditions of sickness, acts irregularly. If, for various reasons, it loses its activity, few or no altered red cells may be expected to be found. But the fact must be emphasised that complete absence of polychromatophilia and basophilic granules in the red cells is exceptional in lead poisoning. This phenomenon is more frequent in old, chronic cases than in acute cases. The bone marrow reacts in the former less promptly and less intensely to the action of the poison than in recent and acute cases. Besides, it is not known at the start if, in chronic cases and elderly subjects, some parallel changes due to vascular sclerosis do not exercise a favourable action on the haemopoietic organs.

Hence arises the necessity for making numerous investigations at frequent intervals.

It is of some practical importance to observe that blood changes, in the majority of cases, are the first sign of a reaction of the blood to lead, even in the absence of subjective or objective symptoms. Such symptoms may, however, be associated from day to day, due to some excess, with intercurrent diseases, or be caused by quite different unknown reasons. It is in the highest degree desirable to acquire further proof of such a state. At all events, blood changes, even when deviating only a little from the normal, are a warning note to the doctor in charge. And, as a matter of fact, how many more times has it been observed that workers presenting blood changes fall sick clinically than those not showing any such lesions of the blood (Engelsmann)?

The idea of there being healthy carriers of lead should then be accepted cum grano salis, and Schmidt, in consequence, adopts a division, proposed by Teleky, into three groups, which include gradations up to the most serious forms:

(1) Lead absorption.

(2) Reaction to lead without clinical symptoms or with some blood changes.

(3) Poisoning by lead with clinical and objective symptoms. With the object of detecting red cells with basophilic granules in case there are only very few, Schwarz has recently recommended preparations with a heavy drop, in which distilled water is used to dissolve the haemoglobin; they enable a much larger number of cells to be examined than is possible in ordinary smears. Schwarz prefers this method as a means of selection when investigating large numbers. In suspected cases recourse can then be had to the method of the normal smear in order to determine the number of granulated red cells, which cannot be done by the method with the heavy drop.

Quite recently (1925), Schwarz has drawn the attention of experts to the value of examining smears, stained by the Manson method, in a darkened field. It is certain that by this method the finding of red cells with basophilic granules is rendered much easier and quicker.

Bianchini and Sestini have shown that basophilic red cells found in a
smear from a heavy drop, but absent in an ordinary smear, represent an artificial product. In reality, as has been said above, rapid autolysis, such as is found in the heavy drop, causes the formation of basophilic substance in small grains, which otherwise would be scattered over the whole element. Thus the results obtained with the heavy drop are regarded as erroneous, rather than as an advance in haematological technique (Biondi).

According to Schilling, the finding of a basophilic network in polychromatophile red cells is quite an easy matter for an experienced doctor, and also enables him to detect cases of anaemia. Schiff, with the same object in view, has used Hoffmann's method of illumination, which had already given good results in the detection of Koch's bacillus. This process is to be recommended in cases where there are only very few granular elements.

By means of this method, Schmidt has been able to demonstrate polychromatophilia, as a very fine granular appearance, through all transitional forms up to basophilic granulation properly so called.

The determination of red cells with granules is greatly facilitated by their splendid colour, which is a golden yellow, the complementary colour to methylene blue. However, it is essential to have a good condenser adapted for changing, so that one can pass easily and without effort from a dark field to a light field and vice versa. In doubtful cases, or rather in threshold cases, the ultramicroscope is certainly most useful, whilst it appears to be superfluous in positive cases.

Researches with the ultramicroscope, made in Italy by Cesarini Demel at Pisa and by Bianchini at Sienna, prove that the change from polychromatophilia into punctate, detected by oblique illumination and by the appearance of the complementary colour, do not justify accepting that red cells with basophilic granules are present with their specific diagnostic significance, unless they can be detected by ordinary methods. Examination with the ultramicroscope may be used to demonstrate, if it is so desired, a fact detected by other methods of investigation, viz. that the basophilic red cell passes uniformly and by degrees to the polychromatophile and the punctate (Biondi).

B. — THE LEUCOCYTES

As regards quantitative alterations in the leucocytes, a diminution of white cells, especially of the polynuclear type, occurs in chronic lead poisoning and chronic mercurialism, and an increase, chiefly of polynuclears, in the acute forms of these poisonings.

It should, however, be mentioned that the leucocytosis varies much according to the type of animal experimented upon, the age, the special condition of the poisoning, and the path by which the poison enters. The leucocytosis also presents a different formula according to the different poisons, which generally cause a neutrophilic polynucleosis. Basophilic polynucleosis is seen most frequently in poisoning by pyridine; eosinophilia in poisoning by carbon monoxide, phosphorus, mercury, aniline, nitrobenzene, benzene, and, practically always, in the final phase of any toxic leucocytotic reaction. In ankylostomiasis, leucocytosis and eosinophilia have been found, which may reach even 40 to 53 per cent., according to Berck, Simon, and Boycott, and only 15 and, more rarely, 20 per cent. in the opinion of such other experts as Bruns and Lieffmann. But generally the rates are from 5 to 7 per cent. In the serious cases alone is anaemia found, which can, however, be very serious and even fatal. Haemoglobin may sometimes fall to 18 per cent.

Lead Poisoning

As in most chronic anaemia, the white cells present, during lead poisoning, changes which betray themselves by an increase in the polynuclear forms and lymphocytes. Naegli speaks of a “moderate leucocytosis” in cases of slight lead poisoning and of pronounced leucocytosis in cases with pronounced anaemia.

Lymphocytosis is also mentioned. What was formerly called the mononucleosis of lead poisoning should be interpreted, according to the researches of Bianchini, as an endotheliosis, that is to say, as an introduction into the blood stream of hyaline corpuscles of reticulo-endothelial origin.

Recently A. Seitz failed to find among typefounders changes in the red cells, but, on the contrary, has found a relative increase of lymphocytes and a diminution of blood platelets. He has ascribed this finding to chronic poisoning by antimony rather than to lead poisoning. Antimony collects and accumulates on the scrapers of furnaces in typefoundries and dust easily forms. Similar results have been obtained in Saxony by Thiele. According to A. Scitz, in consequence of toleration by
the bone marrow of the action of lead, products of this pathological and sudden regeneration are no longer found, whilst a hyperproduction of lymphocytes still occurs. But, since the latest clinical researches allow of the possibility that a mononuclear or basophilic leucocyte, the presence of mononuclear or basophilic leucocytes, although this picture is not characteristic of antimonial poisoning. In mercurialism, Biondi and Giglioli have reported the presence of mononuclear or of basophilic leucocytes.

In anilism, there has recently (1926) been noted by Heim, Agasse-Lafont, and Feil an abnormal increase in small lymphocytes. In a case of serious poisoning by nickel, anaemia was accompanied by an increase in the number of platelets.

The Elements of Diagnosis

The presence of a large quantity of porphyrine in the urine, according to Teleky and Goetzl, is of great importance in the diagnosis of lead poisoning, and more especially in connection with what is called "the lead complexion". According to recent studies of Hans Fischer and O. Schumm, the porphyrin present in urine and faecal material in cases of lead poisoning is not haematoporphyrin, as was formerly supposed, but a koproproporphyrin, for it does not originate from blood haemoglobin, but from myo-haematin by disintegration. The two can be distinguished very easily by spectroscopic examination: acid haematochromoporphyrin has its principal absorption bands at about 593-550 mμ, but not by trional which gives haematoporphyrin, due to poisoning by lead and sulphonal, but not by trional which gives haematoporphyrin, has its bands at 593 and 550 mμ. Alkaline porphyrin is characterised by four absorption bands.

If, according to Garrod's researches, small quantities of porphyrin are present in miscarriages — it is necessary to decide on a standard limit, so that diagnosis may be reliable from a practical point of view. This standard can be easily arrived at by diluting an acid extract until the absorption bands disappear (see further on). Never-the-less, the presence of porphyrin after extensive dilution is not in itself an absolute indication of lead poisoning, for Garrod has found it in a great variety of diseases.

In conclusion, if in the changes in the red cells specific phenomena do not occur — in the sense, for example, of the formation of agglutinins, since polychromasia and basophilia, but specially the first, can be detected in such other forms of anaemia as malaria, pernicious anaemia, leukaeimia, nitrobenzenism, and haemorrhage of long duration, for example, haemorrhages in the mouth, nose, and lungs, and in the injection of the blood in the diagnosis of lead poisoning must not be minimised, more especially when it is a case of detecting the injurious effect on the body in an early stage among certain predisposed individuals with the object of protecting them against more serious injurious effects (Schmidt).

As a simple and objective means of investigation among a number of women workers, nothing can take the place of examination of the blood, and the same thing applies to cases of differences between employers and their
workpeople, between factory surgeons and public health doctors, especially since it can be maintained with complete confidence that, with irreproachable technique and some practice, 90 per cent. at least of new cases of poisoning give positive results on repeated examination. Schmidt has learned from repeated experience that the workers themselves agree readily to a decision, even when it is incomprehensible to them, if it is based on impartiality and science without any subjective taint.

Without wishing to admit that questions of sentiment may arise, it is advisable to demand that decisive examinations shall be done in a central laboratory, where the best methods of investigation are carried out or can be learnt. This idea was recently developed by C. Biondi (see article “Lead Poisoning”), who considers blood investigations of an incontestable value in all doubtful cases, or even in cases not notified, and also when a decision has to be taken as to eventual suspension from work. From this point of view, examination of the blood has a special value, even when the objective signs of the line and anaemia are wanting (Carozzi).

The experience of A. Sellers (1921) among the workmen in an English accumulator factory convinced him that the number of basophilic red cells among those affected by lead poisoning is greater than is generally accepted, and that it is quite easy to find a proportion of 10,000 and even 20,000 basophilic red cells per million. According to his expert, this clinical investigation is simple and can be applied on a large scale. Nevertheless, in counting basophilic red cells difficulties may be met which are not always easy to overcome. But the search for basophilic red cells affords a valuable method in the diagnosis of lead absorption. It is of great use to the clinician, who is enabled to make a diagnosis in slight cases which would otherwise escape notice if the diagnosis had to be based on known symptoms.

Of course suspension from work must not be based simply on an examination of the blood, but on all discovered facts; and regard must be had to the general state of the individual. According to Schnitter, the standard rate of 500 cells with granules per million represents a danger signal, which makes it advisable for workers to leave their work, when industrial lead poisoning is considered as a compensatable accident from the legal point of view; he also says “that the highest pension is a poor consolation for the loss of health”, and suggests in consequence early suspension from work with, of course, compensation. If and in what limits this measure is practically applicable is not a question for discussion here. Examination of the blood provides a supremely important means for early detection of the first effect of the poison on the body, as well as for continuous observation of the features of the blood formula, especially during the early period of exposure to lead risk which is particularly critical.

For all legal decisions, as opposed to prophylactic measures, Biondi undoubtedly does not consider blood examinations as conclusive, even when high rates are present. However, according to Schmidt, the combination of isolated results, especially a high degree of basophilia, for example, more than 500 cells with granules per million, when it is associated with the presence of lead in the urine and the blood, can be considered as conclusive.

It may perhaps be necessary to take into consideration higher rates, for example 1,000 per million, and also the presence of polychromatophilia (Koelsch).

Examination of urine for casts is described by certain authors (Engelsmann, for example) as a means of very great value for controlling the health of lead workers; but it cannot be considered to give better results than examination of the blood. As a matter of fact, experienced clinicians warn us against drawing too rapid conclusions from the presence of hyaline casts, or other similar findings, with regard to the diagnosis of renal disease. Schmidt, for example, has no belief in any parallelism between renal lesions and the results of urinary examinations.

It is necessary then in this important practical question, to accept the opinion of the best qualified experts, who take into consideration the whole clinical picture in addition to isolated symptoms, or require isolated symptoms to be particularly well marked.

It is a fact of great scientific interest that lead may circulate for a long time in the body without causing even the slightest subjective symptoms, or even diminishing the working capacity of those affected. There are many other diseases, especially infectious ones, syphilis for example, which act in the same way. But one day there suddenly appear, while the victim is in full health, the most serious illnesses, often with a fatal issue. It is so with renal diseases and arteriosclerosis, which
may remain latent for a long time and then suddenly cause a catastrophe. Doctors do not possess in these cases any means for foretelling the future; and there is no cause for complaint if investigation for red cells with granules does not enable one to make such a prophecy.

It is probable that the cause of certain phenomena lies in anatomical changes which are caused by the lead in the nerve or muscle cells, but escape notice. Perhaps certain morbid inter-current conditions, such as affections of the circulation, of nutrition or other causes, influence these changes. This is not known. Or perhaps in certain cases of crisis the troubles should be attributed to an unstable nervous system, caused by internal factors completely unknown.

C. — Non-Haemolytic Poisons with the Formation of New Combinations with Haemoglobin

A series of blood poisons exists characterised by the formation of new combinations of the poison with haemoglobin, without, however, leading to destruction of the red cells.

Of these combinations the most important and best studied is certainly carboxy-haemoglobin, while sulphurated methaemoglobin (sulphomethaemoglobin)\(^1\), and particularly cyanomethaemoglobin, are of less importance and so have been less studied from the theoretical point of view. The newly formed chemical bodies are of so stable a character that haemoglobin is deprived of its proper physiological function of carrying oxygen — take, for example, methaemoglobin in its most stable form of oxidation (see article "Carbon Monoxide"). The normal course of oxidation and disintegration processes is so disturbed that combustion of carbon into carboxic acid is prevented or retarded. Dextrose and intermediate products of exchange of various kinds, such as acetone, oxybutyric acid \(\beta\), acetaldehyde, acetic acid, and bodies of the aliphatic series in the urine and the expired air, which are formed in the blood, not only exert a decided influence on the structure of the plasma, displacing the distribution of globulin and changing the strength of fibrinogen, but still more affect the process of disintegration of albumen. The nerve centres suffer chiefly, and suffer first from want of oxygen and exhibit disturbances which may advance to fatal coma.

In view of its great practical importance from an industrial point of view, accurate detection of carbon monoxide must be insisted on, and in particular by simple processes which are available to the factory surgeon (see articles "Carbon Monoxide" and "Air Testing in Workrooms").

The scientific and practical findings of J. and H. Barcroft have shown that the spleen, in consequence of its special vasomotor functions, is in a position to retain carboxyhaemoglobin for a longer time than the circulating blood. According to Nicloux, the amount of carbon monoxide fixed by the blood is not strictly proportioned to the percentage in the air, but it is governed by the mass action of a system where the oxygen and carbon monoxide have an inverse influence on the blood, the curve possessing a parabolic character.

An increase in the number of cells has frequently been found, but it is not constant. Roth is of the opinion that eosinophilia is always absent. From the point of view of the progress of the poisoning, a slight leucocytosis should be considered as indicating a bad prognosis.

Complete elimination of carbon monoxide occurs in the course of five to six hours partly by oxidation into carboxic acid and partly by dissociation and replacement by oxygen (Bolognini, 1912). Administration of pure oxygen causes a dissociation of carboxyhaemoglobin five times greater than when air is used. Still more favourable results are obtained by the addition of 5 per cent. carbon dioxide to the oxygen, for it stimulates more active respiration and the dissociation is by so much the more rapid.

It should be added that red cells of oxycarbonated blood have a greater rate of sedimentation than those of normal blood.

It is an established fact that carbon monoxide is completely displaced by oxygen introduced naturally or artificially without the red cells being destroyed (Bolognini, Lewin). It can at least be said that there is no certain proof of anaemia having been observed after poisoning by carbon monoxide. The chronic forms are said to lead to anaemia; but it is not yet known whether the cause is a destruction of the red cells, or, more likely, a lesion of the haemopoietic organs in consequence of changes of fatty degenera-

\(^1\) See the article "Sulphurated Hydrogen". Howard and Longard is of the opinion that the direct action of this gas does not, in the living body, lead to the formation of sulphohaemoglobin or of sulphomethaemoglobin.
tion, caused by a continuous or even partial want of oxygen.
Next to carbon monoxide, sulphur- 
etted hydrogen plays an important part as an industrial poisonous gas. The only path of absorption which

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<table>
<thead>
<tr>
<th>Length of waves in μμ</th>
<th>Oxyhaemoglobin</th>
<th>Reduced haemoglobin</th>
<th>Carboxyhaemoglobin</th>
<th>Haemochromogen</th>
<th>Alkaline haematin</th>
<th>Acid haematin</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>578.5</td>
<td>578.0</td>
<td>571.5</td>
<td>598.5</td>
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</tbody>
</table>

Spectrum of blood according to Walter J. Dilling (Liverpool)

need be considered is inhalation. for absorption per os by a solution of sulphur- 
etted hydrogen in water is comparatively without danger even in large doses. Sulphur- 
etted methaemo-
sulphohaemoglobin is of a dirty green to brown.

Spectroscopically this substance is characterised by a broad band in the orange at 622 µµ near the bands of oxyhaemoglobin which is always present, whilst neutral methaemoglobin presents a broad band at 634 µµ and alkaline methaemoglobin presents a band at 602 µµ (Rost, Franz, and Heise).

Cyanhaemoglobin, due to poisoning by hydrocyanic or prussic acid, is characterised by a broad band in the yellow-green up to 540 µµ. Cyanhaemoglobin, as well as cyanaemia, which presents an absorption band at the same place, have not up to the present been detected either in the living or dead body, but only in vitro. It is obvious that during life a cyanised combination cannot be produced, for the toxic action is too rapid, paralysing the respiratory and vaso-motor centres before the formation of detectable quantities of cyanhaemoglobin.

Cyanhaematin, which is produced by the addition of hydrocyanic acid to an alkaline solution of haematin, is changed by means of reducing agents into cyanohaemochromogen, characterised by two bands which appear in the green-yellow. If one adds to the blood red cyanide, a body capable of forming methaemoglobin, it does not cause any change in coloration, although this last body may have reacted.

In the same way cyanhaemoglobin, oxynitrated haemoglobin and fluorised haemoglobin, the first a purple red and the second a carmine red, have only been obtained as products of laboratory reactions. Oxide of nitrogen, present in the nitrous fumes which are given off when nitric acid is reduced by means of organic substances or of metals, acts, according to Kunkel, as a nitrite, with a similar formation of methaemoglobin. The red colour of the blood in poisoning by hydrogen cyanide arises, not only from the formation of cyanised haemoglobin, but finally from complete arrest of nutritional exchanges in consequence of paralysis of the cellular enzymes, the cells no longer being able to use the oxygen with which they are supplied. A deep asphyxia of the tissues results, followed by respiratory and cardiac paralysis, long after the nerve cells have ceased their work. Alkalinity diminishes; it is replaced by lactic acid, which can no longer be burnt into carbonic acid.

In all these poisonings repeated exposure, even to small quantities, always leads to anaemia, even though no haemolytic action can be detected; this anaemia undoubtedly arises from fatty degeneration and paralysis of the haemopoietic organs. But as yet no accurate data on these reactions are available.

It should be added that different spectroscopic results are possible owing to variations in concentrations. As some concentrated solutions (1 in 30) completely extinguish the spectrum from the D-ray up to the violet, it is necessary to employ concentrations as weak as 1 in 100, or even lower, in order that the part of the spectrum with the short wave lengths may show up with all its bands.

In a whole series of industrial operations such as the manufacture of acetic acid, soap, margarine, and candles, workers are quite often exposed to the inhalation of acid fumes at an ordinary temperature, but most often at a raised temperature. In some circumstances this danger is very great, both as regards the concentration of the acid fumes, particularly of acetic acid, as well as the length of the exposure. Local lesions, such as ulcerations of the mucous membranes of the eyes and respiratory passages, monopolise the foreground of the picture, for a possible influence on the red cells has up to the present only a theoretical interest. As a matter of fact, in industrial practice cases of haemoglobinæmia and haemoglobinuria have only been noted from accidental absorption of acetic acid by the alimentary canal (Kunkel).

In the same way inhalation of volatile bases, e.g. ammonia and trimethylammon, causes an enrichment of the blood by these products. It is evident that concentration in the blood of bicarbonates and phosphates and of albuminoid bodies causes first of all combinations with and neutralisation of the acids, then follows concentrations of bases rapidly leading to a displacement of the concentration in hydrogen ions. Hober has clearly shown that ammonia can straightforwardly penetrate into the blood stream, but any direct acute effect on the red cells seems not to occur even when the exposure is most pronounced, as, for instance, in the manufacture of ice due to defects in the piping.

The most serious lesions of the system are due to asphyxias or to such local action as spasms of the glottis or pulmonary oedema.
CONCLUSIONS

From this general survey it can be concluded that, while examination of the blood in the domain of industrial hygiene still presents quite a number of problems, it has, on the other hand, given a harvest of obtained results. Speaking generally, it may be said that the methods for examining the blood described above have already gained the full confidence of employers and employed. These methods do not furnish accurate results in 100 per cent of cases, that is to say, not with absolute precision. Such accuracy, however, is unknown in medicine; biology is not mathematics. But confidence can be placed in them, for in 90 per cent. of the cases these methods give a sure result. In the opinion of Schmidt, the time is not far off when the establishment of research institutes for industrial hygiene will not only be asked for but will be insisted on, including in them all the methods of analysis mentioned above carried out by bacteriological methods. These laboratories will not only be for the purpose of detecting injuries already caused, but chiefly for establishing protection against more serious injuries. They will only fulfil this duty when their directors offer adequate and guaranteed skill, as well as a disinterested outlook. Schmidt has given up hope of entrusting to factory doctors such difficult tasks, on account of the time they are obliged to give to the numerous examinations of the personnel of a factory. The work requires such centralisation and unification that the laboratories ought to be State institutions. That no state has so far looked into injuries of this nature and a right of hygienic control is proved by the fact that several of the services for medical inspection of labour, e.g. in Bavaria, Belgium, and Italy, possess laboratories for these practical investigations.

The blood poison which, in the industrial domain, has the greatest importance is lead; it has still a particular significance for the community on account of its influence on the generative organs and the next generation. But the dose of the poison and the duration of its influence to bring about this result are not yet known.

This point alone, according to Schmidt, ought to be carefully studied, since determination of the extent of risk in an industry plays an important rôle, as well as other questions, that is to say, the degree in which, in the course of chronic poisoning by lead, a direct or indirect stimulation of the reticulo-endothelial system is caused with phagocytosis of the damaged red cells and the passing into the blood stream of cell elements. The question arises as to whether this lesion occurs in healthy carriers of lead, or only among those persons affected with poisoning to an extent which can be detected clinically. It may be that there will be found here traces of organic weakness in the hereditary constitution. The way in which such research institutes are linked up to bacteriological laboratories already existing requires explanation. Chemists should clearly be associated with bacteriologists, since the ulterior development of these studies is tending not only in the morphological and clinical direction, but also towards chemistry. Only in this way can an industrial research laboratory be complete.

It is desirable, it might even be said it is necessary, that the study of such questions should be approached from an international point of view, even as is the regulation of the practical results from the point of view of industrial hygiene. With a one-sided, non-international control, apart from any question of narrowness in judgment, risk is run, as a matter of fact, that a nation may suffer from unfavourable competition on the point of industry, on account of the extent of its measures of protection. It is not necessary to insist further on the fact that special local conditions require special measures; the principal general regulations should be the same everywhere. Since it has been found that the social life and health of nations go hand in hand and are more and more interdependent, such postulates are readily understood.

METHODS OF INVESTIGATION

A. — Blood

Staining of Smears

(1) Azur II Giemsa, according to P. Schmidt and W. Koch (Archiv für Hygiene, 1907, Vol. 63, fascicule 1, and 1924, Vol. 94, fascicule 4-6).

Fix for ten minutes in methylic alcohol or twenty minutes in absolute ethylic alcohol.

Stain for two minutes with a solution of Azur II Giemsa (50 mg. per cent. of distilled water of neutral reaction).

Wash rapidly three times and dry.

Stain faintly, so as to bring out better definition in the light. Count
the cells with granules and finally the polychromatophile cells per million so as to establish curves (final determination of cells with granules and polychromatophiles at the same time according to Koch's method).

(2) Manson's blue, stock solution:

Medicinal methylene blue, Höchst
Borax
Boiling water

Grm. 2
2
100

Dilute with water until transparent in a glass reagent vessel and stain for twenty seconds. Wash rapidly.

(3) Manson's blue, modified by L. Schwarz (Klin. Wochenschr., 1st year, No. 49):

Solution I. — Methylene blue
Boric acid
Distilled water (neutral)

Grm. 1
2
100

Solution II. — Caustic soda
Distilled water

0.28
100

Mix in a graduated glass vessel six drops of solution I and eight drops of solution II and make up to 100 c.c. with boiled distilled water. Stain for five seconds, then wash with distilled water.

Preparation in heavy drop according to Schwarz (for rapid examination): stain for three minutes without fixation (see also V. Schilling: Deutsche Medizin. Wochenschr., 1924, No. 36).

(4) Methylene blue, according to Gilbert.

Stain after fixation by ethylic or methyllic alcohol with the following solution:

Ch. pure methylene blue
Bicarbonate of soda
Distilled water

Grm. 2
12
200

Wash until the smear is decolorised.

(5) Blue of toluidine, according to K. B. Lehmann (Archiv f. Hyg., 1924, Vol. 94, fascicule 1, p. 7):

Toluidine blue
Borax
Distilled water

Grm. 3
0.5
1.000

Stain for twenty minutes — twenty-four hours can even be allowed without fear of injury, for it does not cause over-staining. The staining is very delicate.

The double stains (Giemsa or May-Grunwald) are quite unsuitable for the diagnosis of basophilic granules, and polychromatophilia for part of the elements disappears.

B. — Urine

I. Chemical Detection of Blood

(See S. E. Spaeth: Untersuchung des Harns, 6th edition; Leipzig, Ambrosius Barth. — Brugsch and Schittenhelm: Lehrbuch der klinischen Untersuchungsmethoden, 3rd edition; Vienna and Berlin, Urban und Schwarzenberg.)

(a) Reaction of Heller. — Mix in equal parts urine and a 10 per cent. solution of soda; raise to boiling. Haematin is carried down with the precipitate of phosphate which is coloured a brownish red. There is a possible confusion after taking senna, santonic, etc.

(b) Examination by guiacum (Van Deen's test). — Dissolve in some c.c. of absolute alcohol as much resin of guiacum as will go on the point of a small knife; add some drops of oxygenated water or of old oil of turpentine. Make this flow drop by drop through a pipette down the side of a test tube; the reaction is zonal. At the junction of the two liquids a blue ring appears.

The method of O. Schumm enables a more accurate determination to be made: first of all shake the urine with acetic ether, then mix 50 c.c. of urine with 5 c.c. of glacial acetic acid and 50 c.c. of ether.

Allow the urine to flow away and wash with 5 c.c. of water; let that flow away; and use the ethereal extract for the guiacum reaction or for spectroscopic examination.

II. Detection of Urobilin and Urobilinogen

(a) Urobilin. — Mix 10 c.c. of urine with 10 c.c. of an alcoholic solution of acetate of zinc; then filter. The filtrate when the reaction is positive shows a green fluorescence against a black ground (reaction of Schlesinger). If bile pigments are present, eliminate possibly adding to 8 c.c. of acid urine 2 c.c. of a 10 per cent. solution of chloride of calcium. Add a weak solution of ammonia until the reaction is slightly acid; filter and use the filtrate for the test of Schlesinger.

In order to determine urobilin by the spectroscope, acidify 50 c.c. of urine with some drops of hydrochloric acid and stir with 25 c.c. amyllic alcohol. This solution when examined with the spectroscope shows in positive cases the spectrum of acid urobilin towards the F-ray: absorption band at 508-455 μμ.
'b) Urobilinogen. — To some c.c. of urine add some drops of Ehrlich's aldehyde reagent (a 2 per cent. solution of dimethylpara-aminobenzenaldehyde in 20 per cent. hydrochloric acid).

If urobilinogen is present a rose colour is produced, even when cold. This method can only be employed with fresh urine, because, when exposed to light, urobilinogen changes into urobilin.

(c) Biliary pigments. — (1) Reaction of Gmelin. Add to some c.c. of pure concentrated nitric acid some drops of fuming nitric acid. Make the urine run slowly into this mixture so as to obtain a zonal reaction. Oxidation rings are obtained which are, from above downwards: orange, red, violet, blue, and green.

(2) Rosenbach's reaction. Filter the urine several times, and spread out the filter paper on porcelain saucer. With a glass rod put upon the filter paper a drop of a mixture of nitric acid and fuming nitric acid used in the Gmelin reaction. It will cause at the point of contact coloured rings as mentioned in (1).

(3) Reaction with iodide. In a test tube dilute tincture of iodine with absolute alcohol (one part of tincture of iodine to nine parts of alcohol). Add this tincture slowly to the urine to obtain the zonal reaction. At the point of contact will be found a green ring. This method is very good and sensitive.

Biliary pigments can be detected in the serum long before they appear in the urine. They can be discovered by placing 0.1 c.c. serum in a test tube which is as narrow as possible, and adding 0.3 c.c. of physiological solution of chlorid of sodium and then 0.1 c.c. of diazo reagent.

In the presence of bilirubin a red violet colour is produced. In mechanical jaundice (emotional jaundice), the reaction occurs at once; in dynamic jaundice, it is retarded or occurs at the end of thirty seconds.

Diazoreagent is prepared by mixing 10 c.c. of diazo I (sulphanilic acid) with 0.3 of diazo II (nitrite of soda). The reagent when mixed only keeps a few hours. However, this formula has a composition which is slightly different.

(d) Haematochlorophyrin. Koproporphyrin. — The first of these is found in poisonings by trional and in constitutional porphyrinura, and the second in poisoning by sulphonal and lead (H. Fischer and O. Schumni).

Tests for haemoglobin by tincture of guaiacum and by Heller's reaction, and for albumen with heat and with acid, represent the direction investigations should take. In the cases of porphyrinuria the test for haemoglobin by guaiacum is negative, the reaction of Heller is positive and the test for albumen negative.

(1) A. E. Garrod suggests the following special reaction (Journal of Physiology, 1892, Vol. XIII, p. 596, and 1894-1896, Vol. XVII, p. 349): add to 500 c.c. of urine, 100 c.c. of 10 per cent. solution of soda, so as to obtain flocculation and sedimentation of phosphates.

If there is little phosphate of calcium, add a little of it in acetic solution so as to cause a good flocculation with the alkali. If porphyrinuria is present, most of the floccules are of a red colour. Filter the deposit, remove the alkali from the deposit, wash with distilled water, dissolve it in a 5 per cent. solution of hydrochloric acid in alcohol, and then dilute with acid alcohol till the total volume is 50 c.c.

For the spectroscope use a cuvette 4-5 cm. thick. According to Schmidt, only values above 1 in 100 are significant, for koproporphyrin is in small quantity a normal pigment of urine.

(2) Saillot (Revue de médecine, 16, 551) and H. Guntler (Deutsches Archiv für klin. Med., 1920, 134) advise acidifying the urine with acetic acid, making an extraction with acetic ether and adding 5 per cent. hydrochloric acid.

(3) Nebeltau (Neubaur-Huppert: Analyse des Harns, Wiesbaden, 1913) makes the quantitative determination as follows: to 100 c.c. of urine, add 5 c.c. of glacial acetic acid; allow to stand two hours until a deposit forms of impure porphyrin; take up this deposit with chloroform or weak hydrochloric acid. Evaporate to dryness and weigh.

(e) Carbon monoxide (see also article "Carbon Monoxide"). — (1) The tannin method of Kunkel (see L. Lewin: Die Kohlenoxid-Vergiftung, Berlin, 1920): mix one part of a 1 in 4 solution of blood with three parts of a solution of 1 per cent. tannin. Carry out at the same time a test with normal blood as a control. At the end of several hours the normal blood appears as brownish-yellow, and the oxycarbonated blood as pink. The reaction improves with time and will remain for months.

(2) For spectroscopic examination (according to Lewin) a 1 per cent. solution of blood in distilled water is
used with a thickness of 1 cm. The absorption bands show as follows:

<table>
<thead>
<tr>
<th></th>
<th>Normal blood</th>
<th>Oxycarbonated blood</th>
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</thead>
<tbody>
<tr>
<td>Alpha ray</td>
<td>577 μμ</td>
<td>570 μμ</td>
</tr>
<tr>
<td>Beta ray</td>
<td>527 μμ</td>
<td>549 μμ</td>
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</tbody>
</table>

Differentiation is made by adding to the solution of blood some drops of sulphide of ammonia. After a delay of some eight minutes or so a large pale band of reduced haemoglobin appears in normal blood having a wave length of 599 μμ, whilst with oxycarbonated blood there is no change; or when, carboxyhaemoglobin being excluded, there is ordinary oxyhaemoglobin, the absorption band of reduced haemoglobin appears between the alpha- and beta-rays. The presence of carbon monoxide can also be detected by means of white mice.

(i) Methaemoglobin (neutral nitrite-methaemoglobin). — Prepare a solution of blood diluted thirty times. With a dilution of this strength the spectrum is extinguished on reaching the D-ray, whilst a large absorption band is seen in the orange having a wave length of 634 μμ. If the solution is further diluted to 1 in 60, or 1 in 100, the bands of oxyhaemoglobin appear, for, practically, oxyhaemoglobin always remains. Further, a large band appears in the blue at 500 μμ and then the bands in the orange are completely effaced (Rost, Franz, and Heise: Arb. aus d. Katsersl. Gesundheitsamt, 1909, Vol. 32, p. 263).

(g) Sulphomethaemoglobin. — This is very rare according to Kunkel, and according to others has not even been determined with certainty in the living. Examine with the spectroscope a 1 in 60 solution of blood. In addition to the bands of oxyhaemoglobin a broad band appears in the orange red at 622 μμ. By the addition of sulphide of ammonia and potash lye the bands are changed into those of haemochromogen.

(h) Haematin. — According to Schumm, the serum is tested by the spectroscope, using a thickness of liquid of 1 cm. Three absorption bands of acid haematin are found in the red, yellow and green. The bands in the orange red of 633 μμ are characteristic; the others are the bands of oxyhaemoglobin (whilst the bands of methaemoglobin occur at 634 μμ).

The addition of four drops of sulphide of ammonia causes the three bands to disappear, but, on the contrary, causes to appear a broad band of reduced haemoglobin and two bands of haemochromogen at 555 and 525 μμ. Detection in the serum is often possible when the urine is negative, just as in the case of methaemoglobin and bilirubin.

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"Destruction of the Red Corpuscles in Health and Diseases." Studies from the Rockefeller Institute for Medical Research, 1923.


Blood (Changes Due to Occupation)


In this article will be examined briefly modifications in the blood which take place from causes other than toxic. Among the causes of such changes due to occupation the following may be enumerated:

1. Exaggeration of work (physical or intellectual) whether it be a question of continuous or intense effort.
2. Position assumed at work, and, notably, special movements or such as are methodically repeated.
3. Environment of work: surroundings, physical and chemical causes, etc.
4. Materials handled capable of exercising either a toxic or infectious action. (See articles "Blood and Industrial Poisonings", "X-Rays", and "Radium and Radio-Active Substances").

1. Blood in relation to fatigue

Either physical or intellectual fatigue makes its effect felt by all the elements which go to make up the blood. It seems as though the blood reaction is in relation with the kind of work done and the degree of fatigue (Palmulli).

Red Blood Corpuscles

Either an absence of changes (Ferrannini, Scalafatti) or a diminution in the number of the red blood cells has been observed (Wetzell, Broun, Palmulli). The slight diminution found during fatigue might be preceded, according to Palmulli, by an increase in the number of the red blood cells during the first hours of work. Other authorities, however, have found the red blood cells increased (Malassez, Tausk, Hawk, Dürrig), which is thought by one of them (Dürrig) to be the expression of the loss of water by the blood. Villemin, finally, considers that the blood reaction depends on the state of health of the individual. He is said, indeed, to have proved that there is a fall, the result of fatigue, among untrained schoolchildren and a rise among trained subjects.

Haemoglobin

A diminution in the amount of haemoglobin occurs (Dürrig, Broun, etc.), which, according to Conheim, may be 4-5 per cent. in slight physical work, and 10 per cent. in hard work. The same phenomenon is observed with intellectual work (Ferrannini, Graziani), from a long and tiring spell of mental toil. According to certain authors (Löwy), this diminution is in proportion to the number of red blood cells. On the other hand, an increase in the haemoglobin has been observed by Tausk and Palmulli.

Cellular Resistance

The cellular resistance is diminished showing itself in an increase of haemolysin in vitro of the red blood cells, and sometimes by haemoglobinuria in the course of physical fatigue (Manca, Feigl, Carpentieri, etc.) or intellectual fatigue (Graziani). Some authors, on the other hand, have noted an increase of the minimal resistance by exaggerated destruction of the red blood cells which are least resistant to toxic substances arising from brain work (Graziani). Similarly, Lieberman and Acel have shown that the diminution in resistance of the red blood cells to hypotonic salt solutions produced in physical work give place to an increase of this resistance as a consequence of the destruction of the less resistant cells.
Histological Modifications

Without entering into details as to the histological modifications which have been found, it will suffice to recall the fact that a slight increase of the granulo-filamentous material of the red blood cells has been found (Palmulli), as well as, in certain cases, the following changes: poikilocytosis, anysocytosis, punctate basophilia (Pretti).

Leucocytes

The majority of authorities agree in finding a real leucocytosis, which some would maintain had for its object the speedy removal of fatigue substances. The leucocytosis produced by standing upright after half an hour’s punting is well known. Rosenthal found a marked increase after ten minutes in the leucocytes (polynuclear neutrophiles), followed by a diminution and an increase of the neutrophiles.

Other authorities are said to have found only a mononucleosis (Burkhardt), but the majority is of opinion that a neutrophile polynucleosis occurs with sometimes a perceptible increase of the large monoriocellulars (Palmulli). A leucocytosis, described by Hochstetter, and a neutrophilosis would indicate a medullary reaction against auto-intoxication.

Wetzel, on the other hand, is said to have found no changes. Others again have detected a diminution in the number of leucocytes without any change in the differential count (de Sandro).

The phagocytic index is said to be lowered (Guerrini) by the presence of substances inhibiting the leucocytic phagocytosis.

Goldberg and Lepskaja (1927) studied the changes in the differential leucocytic formula during industrial work among 300 healthy individuals and among 134 workmen subjected to static effort. The enquiry covered also intellectual work.

During muscular and intellectual work they found that a neutrophilosis appeared which increased according to the duration and importance of the work; the neutrophiles even reach 80-81 per cent. The limphopenia is at first progressive and relative, but becomes absolute with increase in the intensity and length of the work.

When work is not hard the proportion of eosinophiles diminishes and disappears if the experiment is continued. The monocytes and basophiles increase both with intellectual and muscular work.

If the work is intense or long an increase in the neutrophiles occurs. Young forms appear as well as myelocytes, altered neutrophiles showing basophile, young granulations, plasmocytes and cells of Türck.

The process of regeneration of the white blood cells noted at the commencement of light work occurs in a typical way when the duration and intensity of the work increase.

The leucocytosis during intellectual and physical work, as well as the displacement of the differential leucocytic count to the left, are due to an auto-intoxication resulting from damage to the metabolism and the irritating action of toxic products on the haemopoetic organs.

Plasma

Discordant results have been made so far as the concentration, the viscosity and specific gravity are concerned, because by one observer a diminution and by another an increase is recorded.

The same remarks apply to the time coagulation takes.

An increase of the metrical index of refraction has been noted. The dry residue is also increased (Löwy).

The diminution in the alkalinity of the blood observed by numerous authorities arises from an increase in the hydrogen ions (Dürig) and is due to an augmentation of the circulating lactic acid, to modifications of the chloride exchange between the cells and the plasma, to an increase in the chlorides in the serum, and to the content of the blood in uric acid, total nitrogen and amino-acids.

An increase of the incoagulable nitrogen of the blood (by 20-25 per cent.) has been found as bearing on the value of rest; also of the ammonia in the blood. On the other hand, the proportion of sugar is said to be diminished, but this is less marked in the plasma than in the total blood.

The antitoxic, opsonic and agglutinating, etc., powers — that is to say, the defensive products of the blood — are said to be generally diminished, although some authorities have not found any change.

The blood diastases are themselves modified.

While in acute and chronic fatigue the lipase falls, there has been shown to be an increase of amylase, as well as catalase, which at any rate would diminish in chronic fatigue (Sereni). A hypoglycaemia of fatigue has been observed by Sereni, the glycolytic
Power apparently being increased in a constant way and even more remarkably in the chronic form. The proteolytic ferment is also increased (Sereni) and that increase runs parallel with that of the incoagulable nitroglycerin.

The antitryptic ferment is also increased as a result of fatigue (Preti). The activity in reduction of oxyhaemoglobin diminishes, while it increases during moderate exercise (Ferrannini).

Some authorities have found an increase in the oxygen concentration during work, almost parallel with the increase of the pulmonary ventilation.

Finally, an increase has been observed in the reducing substances of the blood (explaining partly the increase of the blood's toxicity), as well as of the lime circulating in the blood (due to a displacement of the calcium in the system following on the acidification of the muscles in physical fatigue).

It should be clearly understood that all these modifications of the blood are transitory. They last for twenty-four or thirty-six hours; then there is a return to normal.

II. — Position Assumed at Work

This can be a source of physical fatigue on the one hand, and on the other a cause of hindrance to haematosis as a result of an inconvenient position or of some special movement (Ferrannini).

III. — The Blood as Affected by Environment

The modifications due to temperature, pressure, radiations, etc., are very important.

Temperature

The action of high temperatures brings about the following changes:

(1) Diminution of the haemoglobin, especially residence in a warm climate: some authorities, however, have found an increase in the haemoglobin, while others have found an almost normal amount.

Increase in the ordinary temperature of the body, if maintained for a long time, would bring about tissue changes and consequently changes in the state of the blood; a diminution of the haemoglobin would then be found.

In some professions (bakers, mechanics, chauffeurs), changes in the state of the blood have been described; authorities, however, consider that the oligocromenia found (torpedo-boat chauffeurs: Belli) can be attributed to the influence of the absence of natural light and even to the action of certain toxic gases.

(2) In hot countries a diminution in the red blood cells has been reported (Maurel) which, according to some authorities, might be replaced by an increase.

A diminution in the red blood cells, accompanied by other symptoms of anaemia, is found in bakers, glassblowers, chauffeurs, etc. (Ferrannini).

Grawitz has found punctate basophilia occurring, running parallel with the diminution in leucocytes.

Further, high temperatures are said to transform in vitro the oxyhaemoglobin into methaemoglobin (Ferrannini).

The minimal cellular resistance remains within normal limits whilst the mean shows an increase. Lowenthal on the contrary has found a diminution of over 40%. In certain severe cases a profound cellular destuction has been found with jaundice from pleiochromia, haemoglobinuria and even anuria (from blocking of the urinary canaliculars), remarkable anisocytosis, with macrocytes and microcytes, etc.

(3) Leucocytes. — Ferrannini has described a hyperleucocytosis with hypermononucleosis and hypopolymorphonucleosis. The number of white blood cells varies rapidly as the result of excitation by heat (Naegeli). Some authorities are of opinion that the leucocytosis which is found is due to the retention of the leucocytes near the capillaries (Lówy).

Sweating in warm air and electric light baths sets up an increase in the number of white blood cells, which is not the case when a bath of hot water is taken. At the time of the increase in the temperature of the body, Naegeli has observed a reduction of the leucocytes to two-thirds of their normal number. Experimentally (on rabbits) Vincent has shown that at 41° C. no change took place in the leucocytic equilibrium, but that at 42° C. the animal dies with progressive hyperleucocytosis, affecting mostly the polynuclears and the larger mononuclears.

Diminution in temperature hinders the coagulation of the blood and weakens sensibly the activity of reduction of haemoglobin as well as the number of red blood cells.
Cold and humidity have a bad effect on the state of the blood: basophile granules appear; the corpuscular resistance diminishes, and at $-5^\circ$ C. haemolysis sets in (Löwenhail); the number of leucocytes diminishes (owing to vasomotor changes?), while, according to Rovighi, it would increase to double when the body temperature falls to $3^\circ$ C.

**Atmospheric Pressure**

When the pressure falls the effects are felt even after a short and repeated stay at a high altitude (aviators for example). While some authorities have observed a diminution in the number of red blood cells (reaching more than a third), others have not noted quantitative changes either in the arterial or in the peripheral blood. It should be said, however, that the majority of persons with experience are at one in agreeing that the number of blood cells is increased at high altitudes both among balloonists and aviators. Experimental investigations inside the pneumatic bell confirm the data obtained from the actual field of work.

The hyperglobulia, which reaches nearly $7,000,000$ at $1,800$ metres, and $8$ millions at $4,400$ metres, occurs at first quite quickly, then goes on more slowly to reach, in the case of a long stay at high altitude, its maximum on the fifteenth to the twenty-fourth day. Other authorities are said to have found an immediate and constant increase.

The hyperglobia ceases with the same rapidity when the individual descends to low ground. The return to sea level involves a rapid diminution, then a slow one, in the number of red blood cells, until there is a return to normal. While the return to normal takes some days to establish itself after a stay of some time at a high altitude, it does so immediately in the case of a balloon ascent.

Individual reactions play an important role in the production of the hyperglobulia, which is explained in different ways: a real hyperglobulia attributable to an increased activity of haemopoietic tissue with changes in the plasma increasing the respiratory surface of the blood; an apparent one attributable to a thickening of the blood from various causes. An unequal distribution of the blood in the central and peripheral organs may be considered, while the influence of the sun is accepted by some authors and rejected by others.

The amount of haemoglobin may also undergo changes: a diminution or augmentation according to various authorities. Others have not found any modification. Even while the majority accepts the view that there is an increase, they part company on the question of its extent: considerable in the opinion of some, less so in that of others. Whatever be the truth, the increase takes place more slowly than does the number of the red blood cells, and only Abderhalden has found an absolute parallelism between the two.

The activity of reduction of the haemoglobin increases with the climb and diminishes if there is a stay at a high altitude.

The variations in pressure cause the quantity of gases absorbed by the blood to vary. At high altitudes a diminution in the gases contained in the blood occurs.

Authorities are no more in agreement as to the morphological changes in the red blood cells. While some have not observed changes (Snell, Von Schröter), others have noted dwarf cells, an increase in the normoblasts, etc. The alterations in appearance in the opinion of Naegeli are always "artefacts". Further, this authority has never found nucleated red blood cells.

The concentration and specific gravity does not show change. The total volume of the blood on the contrary is said to be increased (Jaquet, Möög, etc.).

The alkalinity of the blood is said to be diminished by $36-44$ per cent. (Galeotti, Agazzotti), and is said to depend on a fall in the amount of carbon dioxide in the blood (Mosso, Marro), as well as to the formation of incompletely oxidised products.

Frenkel and Tissot are said to have found a diminution in the albumens of the serum.

Very different are the results as regards the number of the leucocytes. Generally speaking, a diminution in number is reported with mononucleosis or, as the majority of authorities agree, a marked lymphocytosis. Ruppauer has shown that in going from low ground to high altitudes an acclimatisation leucocytosis sets in lasting for some weeks, with increase in the number of neutrophiles and lymphocytes. It does not appear that there is any relation between the variations of the red and white blood cells.

*High pressures* do not seem to produce changes in the blood.
Luminous Radiations

Excess of light acts especially by the quantity of the radiations and in particular by the ultra-violet rays.

No morphological alteration of the red cells has been described, but, on the contrary, variations in the cellular resistance, which is greatly diminished.

The ultra-violet rays have a haemolyzing action — diminishing the oxidising power of the blood and changing the haemoglobin into methaemoglobin, then into haematin, and, finally, into haemochromogen. Similarly, the carboxyhaemoglobin is converted into reduced oxyhaemoglobin.

Artificial sunlight and light treatment produce an increase in the leucocytes, which, however, diminish in high mountain air. In this case an absolute diminution of the neutrophiles and a relative and absolute augmentation of the leucocytes occur.

Rays from the mercury vapour lamp are said to bring about, according to Bermer, a diminution in the leucocytes and, especially, in the polynuclear neutrophiles, without any increase in the amount of haemoglobin or the number of the red blood cells.

Diminution or suppression of light acts more slowly on the state of the blood. Here, again, the findings are very different because at one time an increase in the number of the red cells and at another a diminution and at another, again, no appreciable change have been described.

Generally speaking, a diminution in the amount of haemoglobin has been prominently stated, more rarely an increase. The oligochromaemia found is not distinguishable from that of ordinary workpeople (Carozzi). Some writers, indeed, speak of occupational anaemia (among photographers: Agasse-Lafont and Heim), which has not been confirmed.

It has yet to be proved that a hyposiderosis and a polynucleosis (slight) is found among night workers. Ferrannini admits a diminution of the morphological elements and of the haemoglobin as the result of complete and prolonged darkness as well as from general troubles.

The polar night causes anaemia (Flugge and Rubner), but only when the hygienic conditions are bad; in the contrary case there is no appreciable change (Nansen and Blessing). Some explorers show, during the polar night, a pale colour inclining to greenish-yellow without corresponding spectroscopic and morphological changes in the blood.

Electricity

The application of galvanic, faradic, or sinusoidal electricity is said, according to Stephens, to bring about a diminution of the leucocytes, which is the more marked the greater the number of white cells (for example, in the case of leukaemia). This diminution (transitory) affects mainly the polynuclears and myelocytes (Veraguth, Seyderhelm). On the other hand, some authorities have found a leucocytosis with relative mononucleosis. Ajello (1927) has taken up again the study of the blood of animals subjected to electrocution and has found a leucocytosis with inversion of the formula. The electric current gives rise, in guinea-pigs, to an alteration of the leucocytic count recalling that due to adrenalin perhaps by intense excitation of the spine.

As to the physical changes brought about in the blood by electricity, Ajello brings out the fact of an increase in the viscosity of the blood (except in fatal cases of asphyxia), a definite increase in the sedimentation rate, more accentuated than that found in fatigue (Sereni). This rapid sedimentation of the red blood cells presenting a curve parallel to those of the increase in fibrinogen, of the diminution of the electric charge, of the lability of the protoplasmatic proteids and of the viscosity, would appear to be due to a colloidal dis-equilibrium, set up by the brusque and intense passage of the current as well as of the prolonged muscular tetanic contraction.

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Boatmen


Though, in effect, Ramazzini speaks in his treatise of the working conditions of sailors and boatmen as well as their pathological conditions, venereal diseases, skin diseases, derangement of the circulation — it is nevertheless true that
no further attention was bestowed on this category of workers until 1906, at the time when the question of the working conditions of boatmen and gondoliers was raised during the first International Congress on Occupational Diseases.

The working conditions of boatmen and gondoliers, compared to that of other categories of workers, were seen in quite a favourable light. The occupations in question are effected in the open air—in sunshine and sea air, which is remarkably free from micro-organisms, excepting in the case of boatmen working on rivers, lakes or canals. The total mortality rate is not excessive; on the contrary boatmen and workers in docks, the latter are chiefly found amongst unskilled workers and dockers engaged in unloading.

The occupations in general shown by the census in the United States was as follows: 1890, 20 per 1,000; 1900, 18.8 per 1,000; 1909, 22.9 per 1,000. Out of 14,469 cases treated in the seamen's hospitals in the United States during the year June 1913-June 1914 there were 2,579 cases of general or local illness with 25 deaths; 11,890 cases of illness with 431 deaths; and of 33,757 dispensary cases, 6,816 were wounds, 31,941 diseases (8,601 of which were venereal diseases), 7,219 respiratory diseases, 2,731 cases of rheumatism, 1,361 diseases of the nervous system, and 679 of the circulatory system.

Shukowsky, of Leningrad, published in 1925 a study on the health conditions of canal boatmen of the north west of Russia. Before the war the health service on this network of canals covering 6,478 versts was absolutely inadequate. Since 1918 the problem of protection of the workers in question has been made the subject of a detailed study. The total number of workers and employers reached, in 1924, 16,562, or 71,313 persons in all, including the members of their families.

STATISTICS

From statistics collected in Italy in 1899 it would appear that 45 per cent. of the sailors and boatmen in question lived to the age of over seventy. According to statistics showing the cause of death amongst seamen, assembled by the Ministry of Labour and Social Insurance in Italy for 1917, it is seen that of 2,860 deaths of seamen (including boatmen, fishermen, etc.) 198, or 6.3 per cent., were due to tuberculosis, as against a proportion of 1,749 per million for the general population.

The sickness statistics established in Naples, covering a group of 300 working boatmen, show the following figures:

<table>
<thead>
<tr>
<th>Disease</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bronchial catarrh</td>
<td>40</td>
<td>13.3</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>18</td>
<td>6.0</td>
</tr>
<tr>
<td>Gonorrhoea</td>
<td>130</td>
<td>43.3</td>
</tr>
<tr>
<td>Syphilis</td>
<td>20</td>
<td>6.6</td>
</tr>
<tr>
<td>Malaria</td>
<td>10</td>
<td>3.3</td>
</tr>
<tr>
<td>Nervous gastric troubles</td>
<td>1</td>
<td>0.3</td>
</tr>
</tbody>
</table>

For the same group at the time of the enquiry the following figures were established:

<table>
<thead>
<tr>
<th>Disease</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Troubles of the respiratory system</td>
<td>25</td>
<td>8.3</td>
</tr>
<tr>
<td>... digestive</td>
<td>92</td>
<td>7.3</td>
</tr>
<tr>
<td>... nervous</td>
<td>5</td>
<td>1.7</td>
</tr>
<tr>
<td>... muscular</td>
<td>34</td>
<td>11.3</td>
</tr>
<tr>
<td>... locomotory</td>
<td>51</td>
<td>17.6</td>
</tr>
<tr>
<td>Cardio-vascular derangements</td>
<td>20</td>
<td>6.6</td>
</tr>
<tr>
<td>Derangement of hearing : deafness</td>
<td>1</td>
<td>0.3</td>
</tr>
<tr>
<td>Ocular troubles</td>
<td>8</td>
<td>2.6</td>
</tr>
</tbody>
</table>

The working day is often nine to ten hours long and holidays often represent additional work. The only rest periods are the outcome of bad weather, which reduces the work. Because of crowding is counteracted, or at least attenuated, by the long hours spent in the fresh air.

A study made by Lowey has proved that sea air does not accelerate nitric metabolism, but that the activity of the circulation and of radiation increases the respiratory exchange, exerting a favourable influence on the digestive system and thus on nutrition in general.

When boatmen are obliged to work in very highly populated districts or near the mouth of sewers they do not, of course, derive the usual benefit of open-air work. As regards boatmen engaged in the transport of cargo, their loads vary from 80-90 kg. for a single oarsman and 300-400 kg. for several oarsmen.

PATHOLOGY

An analysis of the data relating to the diseases of this occupational group has revealed that diseases of the digestive system are the most frequent, followed by diseases of the skin and of the subcutaneous tissue. Whilst the former affect especially boatmen and workers in docks, the latter are chiefly found amongst unskilled workers and dockers engaged in unloading.

The second group comprises diseases of the respiratory organs found to be more frequent amongst boatmen, clerks, and workers. Next in order come infectious diseases, accidents, and, lastly, diseases of the eyes, bones, and muscles.

According to Shukowsky, the morbidity of boatmen is typical; there exists...
in fact for each group of boatmen a clinical picture or a special group of diseases. These characteristics may be explained by the objective conditions and the work of the occupational group in question.

The report of Vitali at the 1906 Congress dealt with the gondoliers and boatmen of Venice whom he had studied for several years. He must specially recalled that the economic position of the gondoliers is better than that of the boatmen, who are often obliged to labour arduously in carrying and unloading weights. The abuse of alcohol is the more frequent the lower the economic standard, and Vitali was often able to discover during post-mortem examination on these workers the existence of chronic leptomeningitis characteristic of wine drinkers, whilst he only rarely met with cirrhosis of the liver as encountered by Viola and typical of alcoholic subjects. However that may be, the harm wrought by alcohol on the system is not very serious, for gondoliers and boatmen show a remarkably small number of cases of digestive and kidney disease.

While the post-mortem findings point to changes due to leptomeningitis and while cases of cerebral hemorrhage and softening of the brain, etc., are fairly frequent, these facts might lead to the conclusion that the harmful effect of alcohol tends to take effect on the central nervous system, favoured perhaps by the action of the sun’s rays on the head or by other physical agents.

On the other hand, respiratory diseases are of very frequent occurrence, taking the form of bronchitis, pleurisy, and pneumonia; cases of articular rheumatism are likewise abundant. Emphysema, favoured by the fairly heavy work, is most often independent of bronchial and pulmonary infections. Rheumatical forms of disease are easily explained by work in all weathers (wind, cold, rain, etc.), wading in water is often the cause of articular rheumatism of the knees and ankles.

Venetian statistics for the period 1903-1905 show 110 deaths amongst boatmen and 71 amongst gondoliers; cases of nephritis only amounted to 9, one affecting a worker of 17 and another a gondolier aged 36.

According to observations made by Vitali, there occurs early development of alteration of the blood vessels (arteries), which are noted even at the age of 25. Yet amongst the numerous cases of atheromatous endocarditis studied the number of patients suffering from aneurism was very small (two cases amongst 1,157 patients). Similarly, the 67 cases of cardiac disease generally took the form of lesions of the myocardium in old patients. Mortality rates due to these lesions for the period 1903-1905 only affected 5 men between 30 and 50 years of age. In the other 33 cases of this trouble (amongst the 181 deaths), the age was always over 50. This proves that the work in question, though onerous, does not prevent boatmen from attaining an advanced age.

Mortality from tuberculosis, which is relatively high in comparison with the general average for the town, is explained by the bad housing conditions and overcrowding, which to a great extent counteract the benefits of life in the open air.

Visual troubles are more or less common. Amongst 2,596 sailors Tschrug found 57 (2.45 per cent.) cases of myopia. Granular conjunctivitis is not unknown. On the other hand, syphilis and venereal diseases are fairly frequent.

Vitali found fairly frequently amongst old gondoliers a characteristic curvature of the spinal column: more or less marked cyphosis of the upper part of the dorsal region, with a compensation curve and sometimes a slight lateral deviation to the right of the lumbar region. However this may be, marked deformity of the skeleton is rarely met with, and it is only amongst very aged boatmen that more or less serious lesions of the thorax are found connected with an emphysematous state of the lungs. A special characteristic deformity has been noted amongst the boatmen of the Rhine and the Rhone, consisting of a depression under the right clavicle and due to the fact that the boatmen press their long boat-hook against this part when pushing upstream. It is possible that this fact may lead to reduced resistance at the point in question, facilitating the development of tubercular infection.

In southern countries continual exposure to strong sunlight often causes hyperaemia of the skin, with redness, swelling and even formation of boils on the less protected parts, followed by desquamation and pigmentation, which disappears gradually or on the contrary becomes permanent if the patient remains exposed to the sun.

To the ultra-violet rays are attributed certain serious lesions and the Xeroderma pigmentosum of Kaposi, which has been noted amongst sailors, together with certain neoplasms which sometimes develop into ulcerated epitheliomata with fatal termination. The salt water as well as the strong light causes, for example, the well-
known affection of the Iceland fishermen, known as "Iceland flowers". Callousities varying in site and in number are formed on the hands of the oarsmen by pressure of the oars. Accidents are of more or less rare occurrence, though contusions of the hands or feet are sometimes met with. It must further be remembered that boatmen engaged in transfer of cargoes run the risk of infection transmitted by merchandise, such as anthrax. In Great Britain since 1920 three cases of epitheliomatous ulceration amongst workers engaged on boat mending and due to tar have been notified.

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Bones Industry


TECHNICAL DATA

Bones differentiated as to their form — long, short, and flat — are composed of a solid substance, slightly elastic, and formed from a nitrogenous organic substance (ossein) and a mineral substance. The ossein may be isolated by treating the bones with dilute hydrochloric acid. It is in the form of a porous elastic mass, from which glue is obtained (see article "Glues"). The inorganic matter is chiefly formed of tricalcic phosphate, the remaining part being various mineral salts (phosphate of magnesia, carbonate and fluoride of calcium, traces of chlorides and of alkaline sulphates). Bones contain, further, water and fats, and in the crude state (before cleaning flesh is also present adhering to the bones in greater or less quantities. The average composition of bones delivered at the factories is as follows: organic substances, 28 per cent. (with 3 to 4 per cent. of nitrogen); phosphate of calcium and magnesium, 45 per cent.; water, 12 per cent.; fat substances, 10 per cent.; carbonate of lime, sand, etc., 5 per cent. It must be stated that the fat content varies according to the kind and condition of the bones, amounting to 8 to 13 per cent. for bones in a fresh condition (ribs, shoulder-blades) and 20 per cent. for long bones.

In the case of bones which have been kept for a long time and are approaching putrefaction, the quantity and quality of fats become reduced.

There are utilised in industry either bones which are, so to speak, local products coming from slaughter houses or knackers' yards, or more often foreign products coming from India and China. The most highly valued bones are those of the horse and of deer. There should also be mentioned bones from kitchens, more or less full of fat, flesh, and nerves, besides exhumed bones which are of much less value, coming from animals which have died of disease and have remained interred for a certain time.

Bones are distinguished according to the ultimate purpose to which they are to be put — bones for the manufacture of such articles as toothbrushes, buttons, rosaries, and numerous other items (such as notes of a piano, engraving tools, handles of sticks and umbrellas, ironmongery articles, turned objects, etc.), bones for the making of glue and manure, including those which are not suitable for the above purposes as, well as the residues of those so used. They are employed in the preparation of glue, animal charcoal, bone ash, bone powder, and artificial manures.

In the slaughter houses and knackers' yards the carcases after stripping are submitted to boiling, which allows of recovery of the fats and bones. Mention should here be made of the bad habit of removing bones from carcases of animals that have been buried, a habit still engaged in in numerous slightly civilised countries.

As soon as they are received in bulk, the bones are generally sorted out in order to separate the long bones (bones of the foot and breast bones, etc., generally intended for the manufacture of objects) from the short or flat bones (bones of the skull and spine, used more particularly for other branches of manufacture).

The removal of fat from the bones must be effected before any treatment of the bones from an industrial point of view. It is carried out by means of three processes: in extraction by water (giving a 50 per cent. return) the bones are placed in perforated receptacles suspended above boilers, the water in which is brought to 100° C. by circulating steam, the grease melts and floats on the top; well as the acidified by sulphuric acid with a view to decomposing the fat soaps containing lime. On the other hand, the action of cold water on the bones enables oil to be obtained (see below). In extraction by steam (return, 75 per cent.) bones are placed in autoclaves into which steam at a pressure of two to three atmospheres is introduced. In extraction by hot water (return about 100 per cent.) or by other solvents (carbon tetrachloride), the recovery
of the fats is effected in special apparatus (series of extractors).

The fats obtained according to the first two processes (natural bone fat, clear bone fat obtained by water or by steam), refined particularly for the treatment of fresh bones or bones in good condition, are of a syrupy consistency and yellowish white colour, with a sebaceous and not too disagreeable odour. The fats obtained by the last process (extraction fats or fats obtained by benzine), especially reserved for old or putrefied bones, are semi-fluid, granular, and clear or brown in colour, with a disagreeable odour. Fats are refined by exposure to light or by treatment with sulphuric acid. They are used in the manufacture of soaps, carbonates, lubricants for vehicles, or in the preparation of bone oil obtained by extraction at a suitable temperature from bone fat of good quality. It is a liquid, yellowish oil without smell and is used for the production of delicate manures and in the hides and skins industry.

For the manufacture of toothbrushes the bones, after removal of fat and drying, are dipped in water and then subjected to the following operations: cutting on a circular saw, washing with water, and drying. The bones (an operation usually effected wet and therefore not liberating much dust) are cut out with a special milling tool, which gives to the brush its definite form; shaping and finishing by hand; cleaning and bleaching by means of hydrogen peroxide. After drying, the brushes are subjected to treatment with pumice stone or Meudon white or borax and water. Thereafter, the brushes are pierced with a series of holes in a horizontal and vertical direction. After insertion of the bristles the latter are cut withippers and the final polishing is applied by contact with cotton buffers dipped in stearin and Meudon white. The waste and the bone dust are used for manures.

Manufacture of buttons involves operations somewhat similar to the above (see article "Buttons"). The same is true of the manufacture of rosaries (cutting in a wet state by circular saw, cutting out the heads, engine-turning on lathe, and polishing in a closed apparatus).

For the manufacture of glue, see article "Glues".

In the manufacture of animal black, the compact bones are carefully cleaned and freed from fat, and, excepting those which have already served in the manufacture of glue as well as the waste from the manufacture of articles made from bone, are ground into small pieces, then calcined in iron or refractory cylinders or retorts connected with condensing apparatus which recovers the products liberated during distillation (volatile organic substances, ammonia, carbon dioxide, water, cyanoxygenc, amoniacal sodium magnesium cyanide, and phosphatic gases, and their derivatives). Calcination can also be effected in a closed apparatus which involves combustion of the volatile gases, but at the same time furnishes an animal black richer in carbon and possessing a greater decolorising activity. After cooling the bones are ground and put through a sieve. The powder obtained is black, opaque, inodorous, and composed of mineral substances thoroughly mixed with carbon coming from the organic matter. The animal black possesses a very great absorbent power for organic substances, especially for colouring agents (decolorising capacity) and for certain inorganic substances (salts of calcium or potassium). Animal charcoal which has been washed (deprived of mineral substances) is obtained by means of washing with hydrochloric acid (increase in the carbon content by dissolution of the mineral salts), thereafter washing in water and drying. Regenerated or revived animal charcoal is obtained by submitting animal black which has been spent to a series of operations: fermentation, washing by acids, alkalis, water, drying, and roasting. The animal charcoal may be regenerated as often as twenty times before becoming unfit for use, when it is finally utilised as manure. It is used in industry for decolorising and purifying sugary syrups, decolorising numerous organic chemical products, and clarifying oils. It is utilised also as a black pigment in oil colours, varnishes and inks.

Ivory black, obtained by calcining in a closed receptacle residues from ivory work, is placed on the market in the form of fine powder with a velvet finish in a paste or small conical pieces. It has been washed and recalcined and to which there is added a small quantity of chrome green in order to neutralise the slightly reddish colour of animal black. It is chiefly utilised for oil paint.

Bone ash, obtained by calcination of bones, contains 67 to 80 per cent. of calcium phosphate, carbonate of lime, sand and water (up to 15 per cent.), oxides of iron, magnesia and alumina, and is used for the manufacture of phosphorous, phosphates, and phosphated manures (as a constituent).

Bone powder is obtained by removing the fat, drying the bones, and grinding them into a fine powder. It contains 3 to 4 per cent. of nitrogen and 19 to 21 per cent. of phosphorous anhydride. In order to obtain a bone powder free from gelatine, the bones, after removal of fat, are treated for eliminating the gelatine by the action of superheated steam. This powder contains nitrogen (14 to 15 per cent.) and phosphorous anhydride (20 to 25 per cent.).

In the manufacture of artificial manures the bones which have first been treated for elimination of fats are ground in a closed apparatus, and the powder obtained is mixed with sulphuric acid in order to render soluble the insoluble phosphates.
SOURCES OF DANGER

Apart from the odour given off either from the storing of bones or in the course of certain operations (elimination of fat, manufacture of animal black, etc.), the sources of occupational injury are represented by the risk of infectious disease due to bones from animals which have died of contagious disease as well as by the presence of dust and steam given off in the course of certain processes.

The danger of infectious disease due to septic cuts or pricks is chiefly of importance in certain operations: recovery of bones from buried animal carcasses, handling, preparation, sorting, and especially transport. In India, for example, 100,000 tons of bone are transported annually, and the very action of placing these in sacks may contribute considerably to the propagation of infection.

Bone dusts are not very harmful, for except during polishing they are not in a fine state of subdivision, which limits their capacity for dispersion, and they lack the harmful asperities which are met with chiefly in the operations of sorting, crushing, grinding, and especially polishing. Research carried out in 1924 in Russia in a bone factory showed, in the air of a polishing room, an atmospheric content of dust amounting to 1,200 mmgr. per c.cm. These dusts were almost exclusively composed (90 to 100 per cent.) of organic substances.

Account must also be taken of products liberated or utilised in the course of the various operations: benzine and solvents used for elimination of fat, liberation of hydrochloric, hydrofluoric, fluosilicic acids, carbonic and sulphurous anhydrides and sulphuretted hydrogen, in the course of the preparation of artificial manures, etc.

STATISTICS

Few statistical data are available. There may be recalled the cases of anthrax in Great Britain in 1913-1914 among workers who were engaged on repairing sacks having contained bone powder coming from Bombay and Egypt. In Japan, out of 9 cases of anthrax notified from 1897 to 1918, 2 occurred in 1913 in the bone trade. In the province of Kagoshima, out of an annual average of 10 cases reported between 1908 and 1919, the majority were similarly due to manipulation of bones. In Germany in 1924 a case of anthrax was reported as having occurred during the manufacture of bone meal. In Great Britain and France cases of poisoning by petrol or benzol used for the elimination of fat during the manipulation of bones have been reported.

PATHOLOGY

Septic scratches may lead to inflamed wounds more or less serious or to specific infections, especially anthrax, which is the most serious and extensive occupational risk in the bone industry. It is necessary also to take into account the possibility of such infections as tuberculosis and glanders, especially in the operations carried out in knackers’ yards and during the preparation of the bones.

Bone dust, besides causing irritating infectious conditions affecting the hands (button-makers’ disease), leads to injury to the respiratory mucous membrane (bronchitis). In the Russian factory above referred to, of 278 workers examined 30 per cent. suffered from lesions of the respiratory system.

The products liberated or manipulated may produce injury varying according to their nature (see articles dealing with such products).

HYGIENE

In the majority of countries, establishments for storing bones, factories for producing animal charcoal, artificial manures, etc., are subject to the general measures of hygiene applied in regard to the liberation of disagreeable odours. Among these measures should be noted: compulsory elimination at a distance (see articles referred to, of 278 workers examined 30 per cent. suffered from lesions of the respiratory system.

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of suspected material as demanded in certain countries and recommended by the Advisory Committee on Anthrax (London, 1922), the Correspondence Committee on Industrial Hygiene of the International Labour Office (1924), and the International Labour Conference at its 1924 Session. Disinfection, already realised in certain industrial operations for the treatment of bones, can be carried out either by heat (boiling for at least fifteen minutes in water at 100°C. or during four hours at least in water at 80°C.) or by the use of chemical products.

Recent research in Japan has revealed the efficiency of disinfection of bones by petrol to which para-formaldehyde has been added. In regard to the recovery of bones from the carcasses of buried animals, certain precautionary measures are essential, and certain countries (Austria) demand boiling during an hour or exposure to heat until the outer layers become carbonised. Special regulations should be provided to safeguard the health of the transport workers who are called on to handle bones.

The wetting of bones prior to manipulation, as well as the execution in a wet state of certain processes, reduce the liberation of dust, but the principal means of prophylaxis consist in an efficient system for dust removal especially in the course of operations such as grinding, piercing and polishing, the apparatus for which should be furnished with local dust exhaust devices. The dust thus assembled is of further commercial value as manure.

As a protection against products liberated or utilised in the course of the various operations engaged in, ordinary measures of prevention should be adopted according to the nature of these.

The transport of bones in closed receptacles and the cleansing and disinfection of these after usage, the wearing of special working clothes, personal cleanliness and the provision of first-aid are equally important as effective preventive measures.

Legislation

Women are excluded from work connected with bones as well as from the manufacture of animal charcoal in Argentina; youths under eighteen years of age in France when dust is given off freely in the workrooms; youths under sixteen in Belgium in establishments where upwards of 25 kg. of bones are handled in a fresh state, and they are likewise excluded from the process of sorting bones, from the manufacture of animal charcoal by carbonising bones and from the regeneration of the same product in workrooms where fat is extracted by means of benzene, and from manufacture of animal black. Youths under fifteen years of age and women under twenty-one are excluded in Japan from workshops where very abundant dust is given off. Youths under sixteen and women under twenty-one are excluded in Spain from treatment in a very dry state of bones involving exposure to dust, and likewise from the manufacture of animal charcoal (en cleaned and passing through sieves) by crushing the residues coming from dried distillation of bituminous schist. Boys under sixteen are excluded from animal charcoal factories in France when dust is given off freely in the workshops.

Special prescriptions relative to the importation of bones have been issued in Austria, France, Italy, New Zealand, Spain, etc. In New Zealand, bone manure may not be imported except from Australia and India, and only then if prepared in certain special factories submitted to authorised inspection.

Importation in special receptacles is compulsory in the United States. Disinfection of bones which have not been cleaned is compulsory in Australia, Canada and the United States. Disinfection of bones can be effected by steam (Austria) or by leaving them fifteen minutes in water at 74°C. (Canada, United States). In Spain, disinfection by sulphur treatment of bones which have not been cleaned and which come from Morocco is provided for by sulphur treatment under certain conditions.

Disinfection for any industrial manipulation is provided for in Austria (Order, 3 August 1918). In France, such disinfection is merely recommended (Decree of 13 October 1913). Compulsory removal of fat from bones is required in Germany (Order, 3 August 1918).

In the Netherlands, in virtue of the Decree of 1916, flooring which can be disinfected is required in workrooms; disinfection of workrooms is required in all cases where it is deemed necessary.

Pulmonary infections encountered among workers engaged on sawing or turning bones are subject to compulsory notification in the Netherlands, as well as cases of tetanus occurring in animal charcoal factories.

Compensation for septicaemia contracted in handling animal by-products is provided in the States of Queensland and Victoria. For anthrax, see that article.

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Boots and Shoes (Manufacture of)


TECHNICAL DATA

The erection of large factories, some of which are indeed model, has brought about a revolution in the boot industry during the last thirty or forty years. But in many cases this industry, and especially that of boot repairing, is still carried on according to primitive methods which favour the development of injuries to health, having their origin in bad conditions of work. Moreover, the industrialisation of the manufacture has led to the adoption of certain methods which are sometimes more injurious than the old ones.

In making by hand, after having cut out with the aid of zinc templates the top of the boot, that is, the leg and the upper — parts which the bootmaker can to-day obtain in the trade ready cut to various sizes — the bootmaker joins these various pieces with the lining by sewing either by hand (home work) or machine stitching. The workman fixes on a wooden last the internal sole which he has cut out and softened; he puts the upper on to the last and fixes it provisionally with tacks. After having stitched together the welt, attaching together the edge of the upper and the lip of the marked sole along the whole length at the edge of the sole, he fills in the inside with glue. He beats the second or external sole of strong leather hard in order to bend it, and fastens it on to the first by stitching or nailing. He then puts on the heel; he rubs the sole and heel with a rasp and glass paper and polishes with blacking.

Hand work is very often done at home (on the Continent by concierges) under very precarious hygienic conditions. The work is undertaken by men who are often old, or by women, but rarely by children.

Machine work was at first limited to stitching uppers and cutting out leather by stamping machines. But to-day the technique is so perfected that it is possible to make boots by machinery with the welt sewn as by hand. All hand operations are now carried out mechanically by means of an extensive set of machines, each of which is so distinct that to make a pair of shoes it is necessary to have the collaboration of a hundred workers and eighty machines.

These operations comprise: preparation of the sides and uppers; stitching the uppers together; preparation of the soles; preparation of the heels; putting together the boots and finishing them.

Women are usually employed on machines which sew together the linings and the uppers. The machines for putting in the eyelets are often worked by men, whilst women work the button-hole machines. The uppers are fixed to the sides by men and women, the lightest work being reserved for the women.

The edges of the uppers, the toe caps, and the sides may be stuck together with cement, which often replaces stitching; it is generally composed of cellulose or celluloid dissolved in a hydrocarbon (see further on).

The process of finishing, which is distinctly heavy work, and entails exposure to the inhalation of dust consists in smoothing and polishing, done by means of a padded wheel often covered with glass-paper or coated with a polishing powder like carborundum. The polishing, blacking and cleaning are also done by machinery.

SOURCES or DANGERS

The use of lead and cadmium for the preparation of footwear in order to give it a metallic lustre, and of barium, magnesia, and talc to increase the density, explains the presence in the atmosphere of workshops of small quantities of these products, which are mixed with copper, kaolin, phosphorus, and sulphur, arising from the pulverisation of debris containing these substances.

The workmen who use cement are exposed to the inhalation of vapours from the fluids used to dissolve India-rubber, cellulose, or celluloid, such as methylic or denatured alcohol, benzol, benzine, acetone, acetate of amyl, chlorinated and brominated hydrocarbons of the methane series, or sulphide of carbon. The same vapours mean a health risk for workmen manipulating blacking materials in which turpentine is commonly replaced by substitutes. The pitch is kept liquid by a small flame, usually of gas, which may expose the workers to risks of poisoning by carbon monoxide.

Some machine processes in assembling cause exposure to heat. The workmen who do the assembling of the boot may be exposed to mercurial poisoning from the fact that for stitching the soles a paste of mercury is used to lubricate the machine (for example, Blake's machine).

The same poisoning has been noted in Russia among felt bootmakers (see article "Hair Cutting"), who almost all work at home.

Gerbis draws attention to the heavy work carried on by men who smooth and polish; they have to hold their work with both hands against the polishing wheel; this position requires close attention and a certain amount of force; it exposes the workers to strong vibration and causes on their hands troubles analogous to those found among men
who work with pneumatic hammers (see article "Pneumatic Tools").
Sardi (1921) had an opportunity of analysing the air of a boot factory, and especially the dust which came off the finishing machines when leather polishing. This dust, which was very fine, impalpable, and slightly brown, gave on analysis the following results: moisture (humidity at 100°) 17.85 per cent.; ash — mineral matter — 0.44; fatty matter (Soxhlet) 0.88; organic extractive matter — from tanning 3.94, not from tanning 1.88; matter coming from leather: tannin 3.14, and dermic matter 43.35.
The ash should always be examined for the presence of lead, copper, kaolin, barium, magnesium, talc, soda, phosphorus, sulphur, and cadmium, which enter into the different industrial operations. But in Sardi's case, lead, copper, and cadmium were not detected.

### STATISTICS

The bootmaking industry can be considered a comparatively healthy one, except as regards tuberculosis. Figures on this point are fairly accurate for some countries. Thus, for example, the National Union of Boot and Shoe Operatives of Great Britain gives the following figures for the period 1913-1923:

<table>
<thead>
<tr>
<th>Age groups</th>
<th>Tuberculosis</th>
<th>Diseases of the heart</th>
<th>Chronic nephritis</th>
</tr>
</thead>
<tbody>
<tr>
<td>25-34 years</td>
<td>1913</td>
<td>1920</td>
<td>1921</td>
</tr>
<tr>
<td>15-24 years</td>
<td>111</td>
<td>111</td>
<td>125</td>
</tr>
<tr>
<td>25-34 years</td>
<td>264</td>
<td>266</td>
<td>256</td>
</tr>
<tr>
<td>15-24 years</td>
<td>41.4</td>
<td>41.4</td>
<td>46.6</td>
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<tr>
<td>25-34 years</td>
<td>45.5</td>
<td>45.5</td>
<td>40.8</td>
</tr>
<tr>
<td>15-24 years</td>
<td>51.4</td>
<td>51.4</td>
<td>51.4</td>
</tr>
<tr>
<td>25-34 years</td>
<td>51.4</td>
<td>51.4</td>
<td>51.4</td>
</tr>
</tbody>
</table>

According to the report of the medical officer of health of Northampton, a bootmaking centre in England, the rate for tuberculosis for workers in this industry was 2.59 per 1,000 against a normal average of 2.08 for the whole population.

A report of the British Medical Research Council (1915) deals with the distribution of tuberculosis in the boot and shoe trade. In Great Britain there has been found a fairly large incidence of respiratory affections and especially of tuberculosis (Greenwood and Tebb), which is twice as high as in industry well organised on modern lines. The factories are as a rule overcrowded and the work is carried on in a badly ventilated atmosphere. The workers are seated all the time.

In the United States, at Lynn, information as to 297 deaths has brought out the fact that in 21.9 per cent. of cases death was due to tuberculosis and in 10.1 to other respiratory diseases. At Brockton (Mass.), out of 167 deaths among shoemakers, 42, or 25.1 per cent., were due to tuberculosis, and 10.1 per cent. to other respiratory diseases. Statistics collected by Hoffmann (1900), dealing with 1,300 deaths, bring out that 371 (19.2 per cent.) were due to tuberculosis and 14.4 to other respiratory diseases. According to the census of 1909, out of 225,435 persons working in the bootmaking industry, men showed 642 days of sickness and women 932, or 0.68 and 0.41 respectively per 100 members. The most important causes of death were as follows:

According to facts collected by the Prudential Insurance Company on the basis of 347 deaths it was observed:

<table>
<thead>
<tr>
<th>Age groups</th>
<th>Number of deaths</th>
<th>Percentage of deaths from Tuberculosis</th>
<th>Other respiratory diseases</th>
<th>Other causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-24 years</td>
<td>111</td>
<td>41.4</td>
<td>4.5</td>
<td>51.4</td>
</tr>
<tr>
<td>25-34 years</td>
<td>125</td>
<td>46.6</td>
<td>8.8</td>
<td>40.8</td>
</tr>
</tbody>
</table>

### PATHOLOGY

Malpositions assumed during work, the pressure of the last and tools against the thorax, and long periods of standing or sitting are favourable to the production of certain deformities of the vertebral column and of the thorax, especially in the case of predisposed persons. According to some authors, the characteristic deformity of shoemakers is a marked depression of the sternum and of the cartilaginous extremities of the ribs. This deformity, commonly called "shoemakers' thorax", is accompanied by a hyperpigmentation of the skin of this region with numerous comedones and a folliculitis due to contact with pitch and the pressure exercised by the last or boot.

Pichler (1919) studied the question of shoemakers' thorax and after a very careful examination of all patients attended by him—several hundred, who carried on this occupation—never found proof that this deformity of the thorax exists.

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1 These rates are higher than the average rates for all occupations.
While it is true that Oriander quotes it as specific, it is also true that Ramazzini, when speaking of certain occupational deformities of the skeleton among shoemakers, does not refer to what is known under the name of “shoemakers’ thorax”. Eichhorst in seven years only found the condition six times among 14,000 patients, and then among persons who were not shoemakers. According to this clinician, this deformity is very rare and is the consequence of work carried out according to a special technique by an individual predisposed by constitutional weakness of the sternum.

Toldt has come across it twice, in a painter and a common labourer, and in examining very closely the method of work he found that the shoemakers rested the last or boot against the lower costal edge rather than against the sternum.

As regards certain stigmata of shoemakers, Oppenheim, as recently as 1924, summarised them as follows:

1. Callosities on the palm of the hand and on the joints at places where the hammer or shoemakers’ knife rests.

2. Callosities of the external side of the right thigh immediately above the patella, due to the pressure of the cramp-iron and the strap on the ischium, when the workman is seated on a low stool. It is due to multiple injuries causing a new connective tissue formation of the subcutaneous cells and of the deep layers of the skin. This trauma arises essentially from blows of the hammer when beating the leather.

3. Deformity in the form of a groove in the folds of the skin of the fingers caused by the repeated passage of tarred and waxed thread.

Shoemakers frequently show injuries on the hands and forearm. Thus, for instance, out of 134,500 Austrian shoemakers during the period 1896-1900 such injuries were found in 10.38 per cent.

A typical lesion is found on the right thigh and is due to the shoemaker’s knife when used for cutting leather. This lesion has been noted from the time of Hippocrates as characteristic of this occupation.

Cutting out soles by stamping machines is a most frequent cause of accidents: in fifty-four Austrian factories employing 14,508 full-time workers, between 1897 and 1900, 77 cases of compensated injuries were caused by these machines.

Among the temporary stigmata, Oppenheim mentions brown and black coloration of the hands and nails caused by handling pitch. Jadassohn and Stahr have recorded that tuberculous verruca cutis and cancer of the thumb are not uncommon among shoemakers. This last statement, however, does not find confirmation in British statistics, for all forms of skin cancer were rare in those statistics, and cases of cancer of the hand do not appear in England and Wales in the period 1910-1912 among shoemakers.

Cases of heart disease are, according to Sternberg, particularly common among German shoemakers. Unhealthy posture, as well as intemperate habits, favour venous stasis, from which arise cardiac diseases.

The frequency of diseases of the heart and vessels among shoemakers has been already noticed by Lancisi and Morgagni. In Austria, from 1900 to 1904 among 124,000 members of the Sickness Insurance Institute the number of cases of incapacity from circulatory diseases was 4,907, of which 765 occurred among shoemakers: 15.5 per cent., as against 10.8 for the average of other occupational classes.

The incidence of respiratory affections and tuberculous infection among shoemakers has been already referred to, and this is favoured on the one hand by work in confined surroundings, and on the other hand by the considerable quantity of dust (animal, vegetable and mineral) which is set free, especially in the workshops for putting together and finishing the soles and heels, for stitching, smoothing and polishing, where the workers are further exposed to vapours from solvents and mastics.

The Austrian experts have noticed the frequency of itch among the shoemaker apprentices of Vienna, which is helped by bad social and hygienic surroundings; the conditions are the same as for baker apprentices. Out of 2,155 cases of itch, 38.9 per cent. occurred among shoemakers. But this affection is much less common to-day. Out of 395 cases of tetanus described in 1896 by Frankl Hochwart, 179 affected shoemakers. It caused a tonic spasm of the muscles of the hands and wrists, which sometimes took on an epidemic character, attributed, according to Koelsch, to lack of cleanliness and to bad hygienic conditions. Cramp or spasm of the muscles of the forearm is also rather common. Cases of lead poisoning and even of buccal syphilis are described in the literature of the subject, as well as...
caries of the incisor teeth caused by the bad habit of holding tin tacks in the mouth and between the teeth.

Too prolonged standing may cause flat foot and varicose veins. The sitting posture causes constipation, haemorrhoids, and disorders of the circulation well known in the pelvic organs of women.

Hygiene

The hygiene of home work by the shoemaker raises the question of general measures of hygiene laid down for dwellings. In the large factory measures to ensure healthy conditions of work are concerned with great cleanliness of the workplace, general ventilation, adequate exhaust of dust and fumes, a high standard for the system of lighting, both natural and artificial, provision of means for personal cleanliness as well as of first aid. There is good reason to believe that the risks incurred in this industry may be banished by means of these hygienic measures. The National Union of Boot and Shoe Operatives of Great Britain has similarly raised the question of a minimum superficial space for each worker. In the closing rooms, where the different parts are sewn together, the women are seated very near to each other. In order to remedy this trouble, chairs for each person have been asked for. Similarly, regular control and efficient working of the system for the extraction of dust is demanded, since it may become operative for want of supervision. The floors should not be littered with waste and should be kept in a good condition of cleanliness. There should be protection for machine workers against the throwing off of bits and various waste. Closed receptacles, supplied with an automatic system of discharge, should be used for cements, the solvent of which gives off injurious fumes. It is advisable to supervise closely workshops where the less heavy work is carried on, or any work done by tuberculous convalescents still incapable of doing their ordinary work, this is in order to avoid their accepting badly paid work which may compromise their chances of recovery.

The State Board of Health of Massachusetts has obtained good results by frequent exhibitions of photographs, of specimens of harmless solvents, and of general measures of hygiene.

Legislation

As regards legislation, Quebec excludes boys of less than sixteen years and girls of less than eighteen years from polishing and mechanical abrasion with glass paper in boot factories. A resolution relating to safety in the boot industry was passed by the Finnish Government on 17 May 1927.

Brass


Brass is an alloy of copper with a base metal, usually zinc, but sometimes tin; it contains also varying quantities of other metals. Fine brass or red brass consists of two parts copper and one of zinc. However, as these two metals combine in practically all proportions, many alloys are possible. "Cheap yellow brass" is very rich in zinc.

The making of brass was known to the Phoenicians before Solomon's time. Pliny describes brass fumes. The copper of the Bible was probably brass.

To facilitate work on a lathe or file, lead is added (0.5-10 per cent.) to brass alloys.

Bronze is an alloy consisting of copper nine parts to tin one part. In the industry, however, red brass is very often styled "brass", although zinc is the other component instead of tin. Many metals and metalloids are added to brass and bronze to convey certain physical properties. Aluminium, copper, and German silver castings are other products.

Usually, in foundry work, scrap metal, consisting of all sorts and compositions of (non-ferrous) metals, makes up one-third or more of the alloy; then copper, zinc, or lead ingots are added, to arrive at an approximate composition. Consequently it will be seen that the brass manufacturing industry, or more properly the non-ferruginous metal-working trade, is engaged in the handling of large amounts of copper, zinc, and tin, while it must not be overlooked that lead, antimony, nickel, aluminium, cadmium, manganese, iron, phosphorus, arsenic, and sulphur may enter the brass crucible. In subsequent processes of cleansing, plating, and finishing, dangerous acids and cyanide solutions are used.

The possibility of continuously varying the percentage composition in these alloys suggests an analogy between an alloy and a solution, and A. Matthiessen (1860) applied the term "solidified solutions" to alloys, but modern work has shown that although alloys sometimes contain solid solutions, the solid alloy as a whole is often far more like a conglomerate rock than a uniform solution. If, however, after polishing a plane face on a bit or file, the new surface is examined with a microscope, the structure will be found to be a conglomerate of grains, each of which is an alloy of the complex nature of the solid solution.
a lens or a microscope, a complex pattern of at least two materials is found. The act of etching the surface has darkened the parts richest in copper, while the parts richest in tin remained white. The two ingredients revealed by this process are not pure copper and pure tin, but each material contains both metals. Higher magnification will show that each such portion is in itself a complex. The majority of alloys, when examined thus, prove to be complexes of two or more materials, and the patterns showing the distribution of these materials throughout the alloy are of a most varied character. The Latin word aes signifies either pure copper or bronze, not brass, but the Romans comprehended a brass compound of copper and zinc under the term aurichalcum, into which Pliny states that copper was converted by the aid of cadmia (a mineral of zinc).

There is every reason for believing that brass and zinc were already manufactured in Great Britain at the end of the sixteenth century.

When a small percentage of zinc is present, the colour of brass is reddish, as in tombac or red brass, which contains about 10 per cent. With about 20 per cent. the colour becomes more yellow, and a series of metals is obtained which simulate gold more or less closely; such are Dutch metal, Mannheim gold, similor, and Pinchbeck, the last deriving its name from a London clockmaker, Christopher Pinchbeck, who invented it in 1732. Ordinary brass contains about 30 per cent. of zinc, and when 40 per cent. is present, as in muntz — yellow or patent metal, invented by G. F. Muntz in 1832 — the colour becomes a full yellow. When the proportion of zinc is largely increased the colour becomes silver-white and finally grey. The limit of elasticity increases with the percentage of zinc, as also does the amount of elongation before fracture, the maximum occurring with 50 per cent. The tenacity increases with the proportion of zinc up to a maximum with 45 per cent.; then it decreases rapidly, and with 50 per cent. the metals are fragile. By varying the proportion between 30 and 43 per cent. a series of alloys may be prepared presenting very varied properties. The most malleable of the series has an elongation of about 60 per cent., with a tensile strength of 17.5 tons per square inch. Increase in the proportion of zinc gives higher tensile strength, accompanied, however, by a smaller percentage of elongation and a materially increased tendency to produce unsound castings. The quality of copper-zinc alloys is improved by the addition of a small quantity of iron, a fact of which advantage is taken in the production of Aich's metal and delta metal. Of the latter there are several varieties, modified in composition to suit different purposes. Some of them possess high tensile strength and ductility. They are remarkably resistant to corrosion by seawater, and are well suited for screw propellers as well as for pump-plungers, pistons, and glands. Heated to a dull red, delta metal becomes malleable and can be worked under the hammer, press, or stamps. By such treatment an ultimate tensile strength of 30 tons per square inch may be obtained, with an elongation of 32 per cent. in 2 inches and a contraction of area of 30 per cent.

In the arts brass is a most important and very used alloy. As compared with copper its superior hardness makes it wear better, while being more fusible it can be cast with greater facility. It is readily drawn into fine wire, and formed into rolled sheets and rods which are machined into a huge number of useful and ornamental articles. It is susceptible of a fine polish, but tarnishes with exposure to the air; the brilliancy of the surface can, however, be preserved if the metal is thoroughly cleaned by "dipping" in nitric acid and "lacquered" with a coating of varnish consisting of seed-lac dissolved in spirit.

**Industrial Operations**

The foundry workers receive the iron moulds containing zinc and fragments of copper generally in the proportion of two to three or one to three, as well as pieces of recoverable brass. The copper thus prepared is placed in crucibles, which are lowered into furnaces having a temperature of over 900°C. These furnaces are heated with coke. At present attempts are being made to introduce other types of furnaces less objectionable from a health point of view.

The crucibles are kept from fifty to sixty minutes in the furnace. When fusion is complete they are withdrawn from the furnace by using large tongs and the liquid brass is poured into the moulds or casts. Towards the end of the fusion, when the crucible is ready to be removed from the furnace, some zinc, almost pure, is added and in certain cases lead.

All the operations liberate metallic fumes, and in the absence of provisions for confining or removing them they fill the atmosphere and are inhaled by all those in the vicinity.

After casting, the foundrymen are relieved by other workers whose task it is to attend to the second firing required to render malleable the unduly thick brass plates, and thereafter to engage in rolling, finishing, and polishing.

Rough finishing is accomplished in several ways. One method is by chip-ting the rough castings with pneumatic chisels (an extremely noisy process), or by means of "sand blasting". In some of the factories the smaller castings are cleaned by hand with steel wire brushes.
on the final burnishing of brass is done sand an.d all rough surfaces. Other and the scrap iron removes the pieces of scrap iron and then rotated in brushes, or by being mixed with small or mechanical revolving wire brushes. The constant friction of the castings upon each other and the scrap iron removes the sand and all rough surfaces.

Polishing is usually accomplished by the employment of emery wheels, and the final burnishing of brass is done on "buffing wheels" covered with leather or circular pieces of cotton cloth. All the processes referred to are extremely dusty and expose the operatives to the inhalation of a conglomerate of dust with injuries to the eyes and respiratory mucous membrane.

Many castings are further subjected to plating, for which a cleansing dip in acid solutions is preparatory. Acid fumes arise when the castings are dipped into mixed mineral acids for cleansing them. A hood and vent pipe connected to a window or stack should be provided above the vats. Hot potash solutions stand usually in large vats. Breathing over them causes a dryness of the throat and an irritating cough. A low-hung hood with connection to proper stack should be suspended over such vats. Potassium cyanide is the compound used in these solutions, which are hot and stand in open vats. These should be provided with hoods and vent pipes if solutions are strong enough to emit the characteristic hydrocyanic odour. Also dipping the hands and arms in such solutions causes the intractable cyanide ulcers. Poison signs should be conspicuously displayed.

Final protection and gloss is given to castings, tubings, etc., by varnishing method. The vapours from the solvents used (wood alcohol, amyl acetate, benzine, etc.) cause irritation to the eyes, the respiratory tract, and occasionally the chronic forms of sickness usually ascribed to these poisons. If the hands are kept free of the solutions, the brushing and dipping processes are less harmful, but all spraying and atomising processes are deadly and demand cabinets with exhaust fans. The use of Japan mixed with wood alcohol and of Zapon lacquer (amy! acetate) as a final finish to chandeliers, art goods, etc., is injurious to the health and calls for special protection in the way of exhaust ventilation and steam-heated drying chambers.

**Sources of Risk**

The causes of injury are chiefly dust and fumes. It is well known that the fumes given off by the metal during melting, stirring and casting are the cause of "brassfounders' fever".

Other causes of injury are lead and antimony utilised in special processes; smoke liberated by oils, which causes nausea and vomiting; the high temperature, which causes abundant sweating and so exposes the workers to dangerous variations in temperature (opening of furnaces, stirring of metal, etc.), to rheumatism, fatigue, exhaustion and strain, lumbago; the gases escaping from the furnace (at the moment of opening the doors, to stir the casting): carbon monoxide, sulphur dioxide, etc.; the coal gas given off at the beginning of the process before the metal is molten; carbon monoxide, and carbon dioxide; thereafter the zinc commences to melt and carbon dioxide and zinc oxide fumes are given off. At the end of the operation of melting, when zinc in an almost pure state is poured into the crucible, a very perceptible liberation of oxide of zinc occurs in the form of tiny flakes, which rise in the air to fall again like a shower of snow. At the moment of casting oxide of zinc fumes are given off and when the crucible cools and when the crucible cools there is seen in it a white deposit, which is zinc oxide.

Besides injuries from the above causes account must likewise be taken of other products utilised in this industry: benzine, phosphorus, carbon disulphide, etc.

**Statistics**

In France the enquiry carried out by F. Heim de Balsac, Agasse-Lafont and Feil (1926) in a brassfoundry led to the collection of very interesting data in regard to brassfounders' fever.

Of 18 workers in the factory visited 13 had had fever. After leaving work, without experiencing discomfort the worker becomes stiff and prostrated; he suffers from trembling of the limbs, shivering, sometimes nausea, dyspnoea, headache. After going to bed he still shivers, his temperature varies round 38-40°C. After three or four hours the end of the attack is marked by abundant sweating. The following day, though a little stiff, the worker is usually able to follow his occupation.

Among the symptoms noted but not typical of these attacks may be mentioned cough, dyspnoea, asthmatic symptoms (due to irritation by zinc fumes), digestive derangements (nausea, vomiting). There has also been noted a sweetish taste in the mouth, which may however give place to a metallic taste.

Examination of the blood has shown that the red corpuscles are normal, a tendency to mononucleosis and usually a normal number of eosinophiles. This question receives more thorough consid-
eration in relation to etiology and pathogenesis in the article "Zinc".

Legge states that in Great Britain the mortality figures found in the Decennial Supplement of the Registrar-General (see later) show that there is undue incidence of phthisis among those employed in brass work. The industry is an extensive one in Birmingham where there are approximately 860 casting shops.

An enquiry carried out during the years 1910-1912 reveals a mortality percentage by tuberculosis for brass and bronze foundry workers higher than that for workers in other occupations. These figures correspond approximately to that found for the industries rated as the most dangerous.

The workers engaged in "dipping" are exposed to inhalation of acid fumes as well as to danger from standing on a wet floor. The polishers work in an atmosphere loaded with metallic and mineral dust containing particles of chalk from the polishing buffers, and they suffer from chronic bronchitis, tuberculosis, and pulmonary silicosis.

7 out of 1,200 brassfounders only 1 lived to be over sixty, and 3 workers only among those insured with the Brass Workers' Association were found to have survived the age limit fixed at fifty-five.

During the year 1921 the Registrar's death returns for the City of Birmingham showed that there were 508 deaths from pulmonary tuberculosis amongst males of fifteen years and upwards, and of this number 9.2 per cent. occurred among brassworkers, and in 1922 51 out of 508 deaths were recorded for these workers. These numbers were the largest for pulmonary tuberculosis associated with any occupation during the period, notwithstanding the fact that brass work, although an important section of the city's industry, was not the one giving employment to the largest number of persons.

G. B. Dixon reports in 1927 for Birmingham that the mortality percentage rate for pulmonary tuberculosis in that city for scissors makers is 34.5; file makers, 27.4; boot, shoe and slipper makers, 34.2; and brass and bronze workers, 27.3. The per capita mortality rate for pulmonary tuberculosis of males between the ages of twenty-five to sixty-five in England and Wales, for the period 1910-1912, was 17.8.

The comparative mortality figure for brassfounders (all causes) as given in the Registrar-General's Decennial Supplement (1921-1923 : England and Wales) is 1,530 and is exceeded by only fourteen other occupations. At the ages of sixteen to twenty their mortality is three times the average and it attains its maximum, 202 per cent., at the ages of thirty-five to forty-five. Mortality after sixty-five is not high, probably as a result of instability of occupation. The following are the mortality figures for various diseases, as given in the Supplement, for brass furnace men: influenza, 4 per cent. bronchitis (only exceeding grinders); phthisis, 164; cerebral haemorrhage, 168; myocardial disease, 156; bronchitis, 151; pneumonia, 178 (the highest figure for the 178 occupational groups dealt with); digestive diseases, 152. Mortality from accidents, 205.2 per cent., is above the average, and that from influenza, phthisis, pneumonia, respiratory disease in general, cerebral haemorrhage, and emaciation is more than double the average.

Guellman (1925) found among the Russian brassfounders that, in addition to well-known symptoms, the patients sometimes suffered from mydriasis, conjunctivitis, and a more or less marked irritation of the throat and of the face. He found sugar in the urine, also porphyrine and increased urobiline and indican.

In the United States the percentage mortality from tuberculosis among brass workers is twice that of iron and steel workers. Of 201 brass workers, 31.3 per cent. died of pulmonary tuberculosis, 9.4 per cent. of pneumonia, 8.4 per cent. of cancer, 8.0 per cent. of accidents. Hoffman's figures for 1897 to 1914 show 633 deaths, the consumption rate being 36.7 per cent. He says: "The proportionate mortality from pulmonary tuberculosis is decidedly excessive at all ages under sixty-five", and most so at fifteen to twenty-four, when out of every 100 deaths from all causes 58.2 per cent. are from consumption, against a normal expected proportion of 27 per cent. Insurance premiums on brassfounders, moulders, and casters are considerably above the usual rates. Those in finishing processes, including grinders and polishers, have more privileges or are not super-rated at all.

In Chicago the fact that 85 per cent. of 1,761 foundry workers were under forty years of age, and only 1 per cent. over fifty years was explained by employers as due to "slowing up", or incipient degeneration, and by workmen as gradual incapacitation from the inhalation of brass fumes and the strain of the work. The constant intake and elimination of unusual amounts of zinc and copper from the system, along with the repetition of brass chills or the constantly forced immobility to the same, are enough to cause degenerative diseases in themselves, even though the immediate affilictions above mentioned are overlooked. Chronic bronchitis or "asthma", emphysema, and pulmonary tuberculosis are very common. Observations invariably come under dyspepsia, "biliousness", and they are often icteroid. Pyorrhea alveolaris, carious teeth, gastro-enteritis, sallow complexion and anaemia, ill-nourishment, emaciation, and alcoholism, Bright's disease, nervous and heart diseases are all above the average.

In 1926 the enquiry conducted by A. Turner and R. Thompson into conditions in 22 brassfoundries employing 340 workers revealed that 33 to 64 per cent. had suffered from brassfounders' fever. An analysis of the air in workrooms showed that the air was contaminated by (a) fogging from manganese, iron and antimony lead, and naturally large quantities of zinc oxide.
Of the 212 workers medically examined, 102 exposed to inhalation of fumes of zinc oxide had had the fever; 68 likewise exposed had never had it; 42 had never been exposed to the fumes. In the first group, 26 per cent. had had one attack of fever per week; 11 per cent. two attacks per week, and 2 per cent. three attacks per week. On an average the sick workers had had from one attack per month to one or two attacks per annum.

These attacks occurred chiefly during the cold season or when the weather was heavy. It should be stated that 18 per cent. had grown acclimatised to the action of zinc oxide, and that the workers who had never suffered from the effects worked in well-ventilated workrooms.

**Pathology**

Wounds due to brass objects and similar alloys are of traumatic and infectious significance only. Brass dust (grinders, polishers, and buffers) does not produce brassfounders' ague, and has only the harmful effects of metallic dusts in general. The lead in the alloy-dust may produce its symptoms in very susceptible persons. Brass in any condition, short of the recent vaporous state of its components, produces no intoxication peculiar to itself, Ravogli has, however, reported a case of dermatitis with irritation, redness and oedema of the skin, affecting a brass polisher.

The essential health-hazard from brass is the inhalation of the metallic fumes. Analyses of brass fumes show:

<table>
<thead>
<tr>
<th>Substance</th>
<th>Deposits from flues</th>
<th>Analysis of fumes</th>
<th>Bench-settling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Zinc oxide</td>
<td>32.13</td>
<td>24.74</td>
<td>28.82</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead oxide</td>
<td>0.31</td>
<td>1.92</td>
<td>-</td>
</tr>
<tr>
<td>Iron oxide</td>
<td>2.43</td>
<td>-</td>
<td>2.78</td>
</tr>
<tr>
<td>Copper oxide</td>
<td>2.83</td>
<td>2.50</td>
<td>1.71</td>
</tr>
<tr>
<td>Cadmium oxide</td>
<td>1.58</td>
<td>0.89</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(copper)</td>
</tr>
</tbody>
</table>

Insignificant traces of arsenic, nickel, and manganese may be present, and Sigel found the chills where copper was absent in the fumes. Symptoms traceable to phosphorus in phosphor-bronze and manganese in manganese-bronze have rarely been reported. Antimony poisoning occurs, however, among type-metal refiners and molers, and dermatitis and "bbling nasotracheitis attacks the mouth. It distinguishes itself from "brass itch" and "zinc asthma" respectively. Braziers and hard-solder workers, especially where electric welding or the modern blow pipes (oxy-acetylene, oxy-hydrogen) are used, may suffer greatly from metal chills due to volatilisation of the alloys worked upon.

Brassfounders' ague is the only condition which can be recognised under this heading, and this is described under zinc, where it properly belongs. The condition was first mentioned by Thackrah in 1832, who considered it periodic because seasonal; the zinc factor was recognised by Blandet in 1845 and reaffirmed by Greenhow in 1862, Boudet, Sigel, etc. The earliest American cases were cited by Oppenheim in 1894, while later references are Moyer and Lavin, also Pietrowiecz (Chicago, 1904), Sicard (New York, 1905), Hayhurst (Illinois, 1910 and 1912), and Reisman and Bolis (1917), etc.

Brassfounders' ague, also called brass fever or brass chill, has many synonyms, while the workmen use cruder terms, such as "the shakes", "smelters' shakes", and "zinc chills". Brassfounders' ague is an acute, malaria-like sickness, which comes on in the foundrymen or any who are exposed to the vapours which arise from the metals. Practically all recent investigators regard it as an expression of acute zinc poisoning. Certain authorities, however, hold that the part played by zinc is only a secondary one, or even that it does not exist (Guérard, Lehmann, Laborde, Courtois-Suffit, Marcel Finard, etc.). These experts blame other factors such as excessive heat from the furnace, fatigue, dust (repeated poisonings, etc.).

Lehmann (1910) was the first to produce typical attacks of the "ague" with pure zinc fumes and prove the characteristic symptoms to be due to zinc fumes. He also recovered zinc in the urine (see article "Zinc"). The same or similar symptoms are now known to be caused by the breathing of the fumes of various metals, particularly copper, nickel, iron, cobalt, and cadmium.

Drinker and his collaborators point out that the metal fume fever reported in literature was generally caused by the inhalation of freshly formed zinc oxide fumes. It has long been thought that it did not exist until handled zinc oxide powder, but Hayhurst, and before him Bassett (1912), found same to occur in the bagrooms where zinc oxide was manufactured.

Koelsch, in July 1923, reported that attacks had been observed in cases in which inhalation of ordinary fumes caused in very finely divided powdered form had produced the characteristic symp-
toms, similar to those produced by
vapourisation. Drinker confirmed this
by experiencing, with a colleague, attacks of fever on inhaling finely
ground zinc oxide powder called "Kadox", particles of which were of
the order of 0.4 microns in size. The "Kadox" had been dried overnight at
110°C. and while still hot was blown into the cabinet where the experimentors
were located. Koelsch likewise reported
cases of the characteristic ague (metal
fume fever) from the inhalation of
finely divided copper oxide. Likewise,
inhalation of sprays of silver, copper,
zinc, mercury, iron, cobalt, and anti-
mony compounds may, according to
Koelsch, bring about a rise in tempera-
ture. Drinker mentions several in-
stances of similar symptoms from,
breathing fumes from burnt cadmium.
From this it may be seen that the
long-known brassfounders' ague is not
specifically due to this alloy, but is the
commonest of the metal fume fevers due
to the extensive use of zinc in an alloy
whose melting point is above the boil-
ing point of zinc.

HYGIENE

Strict provision is required in the
brass foundry, since much remains to be
done as regards the introduction of
measures of hygiene with a view to
eliminating risk of injury.

A well-arranged foundry is a roomy,
one-story building or top floor, with
impervious flooring, ceiling vents, large
windows, and unhampered by high
surrounding eminences. It is divided
into: furnace room, or at least partial
partitions providing adequate up-and-
down ventilation in the furnace area;
casting room, or an area covered by
broad spreading exhaust hoods beneath
which pouring is done; moulding shop,
where moulds are made (an entirely
cold process); core room, which has the
core-baking ovens well apart; chipping,
grinding and sand-blasting rooms,
equipped with exhaust ventilation,
where rough castings are smoothed
down; washing facilities consisting of a
sanitary trough, or small places, with
hot and cold water and an open outlet,
and, for larger places, a change house
or quarters provided with lockers on
one side for street clothes, shower baths
in the centre, and lockers or, better
still, ceiling hangers for work clothes
on the other side; sanitary drinking
water devices, preferably angle-stream
bubbling fountains; and luncheon quar-
ters.

Furthermore, prophylaxis consists in
selecting workmen through physical
examinations, regulating their habits
and work, then limiting, confining, or
removing the fumes. The adoption of
the electric furnace promises much in
this respect. Aerial dilution of the
fumes is insufficient. All furnace
areas and pouring areas should be pro-
vided with hoods and stacks to draw
off vapours. The Germans use flexible
exhaust ducts which are locally applied
during pouring. In addition, the found-
ry rooms need air-agitators (fans),
and arrangements for vertical (floor-
celling) ventilation which is most apt
to be efficient irrespective of weather
and wind conditions. The wearing of
respirators, although a help, will not
prevent the inhaling of gas or fumes.
The more zinc oxide in the air the
more imperatively are regulations and
improvements needed. Illumination is
often most inadequate in foundries due
to insufficient lighting units, absence of
reflectors, dirty windows and lamp
bulbs, and obstructions in general.

Certain precautions are necessary to
remove dangerous acid fumes (not-
ably nitrous fumes) which are evolved
in metal pickling, especially of brass,
articles for the purpose of giving them
a shiny or a dull surface. Severe and
even fatal poisoning has occurred in
this operation. An acid-proof earthen-
ware fan or an injector is necessary to
promote mechanical ventilation. The
fumes are caught in an absorption
tower filled with cone-shaped packing
material, through which water trickles
from a vessel placed at the top. The
fumes thus pass into solution in the
water which is changed when it
becomes unduly charged with acid.

LEGISLATION

In practically all progressive countries
there has been some legislation respecting
the brass industry. In Great Britain,
for the casting of brass, occupiers must pro-
vide proficient exhaust draught by means
either of (i) a tube attached to the pot,
or (ii) a fixed or movable hood over the
point where the casting takes place, or
(iii) which may be provided with a fan
in the upper part of the casting shop to
stimulate ventilation, or (iv) some other
effectual contrivance for the prompt re-
moval of the fumes from the casting shop
and preventing their diffusion therein.
A lavatory under cover, with sufficient
supply of clean towels, renewed daily,
and of soap and nail brushes, must be
provided, with wash troughs to allow
at least two feet for every five persons,
or a lavatory basin for every five persons.
No female is allowed to work in any
process whatever in any casting shop.
Employees are requested not to leave the
premises or to partake of food without
carefully washing the hands, and the em-
ployed person must use the apparatus provided for the removal of fumes. Injuries due to brass are subject to compulsory notification in parts of the United States (Connecticut, Massachusetts, Missouri, New Hampshire); in Pennsylvania, brassfounders' ague only; while compensation is compulsory in the States of Illinois, New York, and Ohio (see article "Zinc").

BIBLIOGRAPHY


Prof. E. R. Hayhurst
(Ohio).

Breathing Apparatus, Respirators, Gas Masks

French: Appareils respiratoires (Appareils protecteurs des voies respiratoires, Masques).

German: Atmungsapparate, Gasschutzmasken, Respiratoren.

Italian: Maschere o Apparecchi contro i gas, le polvere.

Spanish: Mascaras respiratorias.

By the formula "apparatus for the protection of the respiratory tract" is to be understood apparatus designed to protect the individual either against every kind of poisoning or against every attack on the respiratory tract itself, such poisoning or attack originating in the physical-chemical composition of the inhaled air.

The determining causes of these risks are especially dust, smoke, fumes, and offensive or toxic gases.

The means taken to combat them are to place the respiratory tract out of their reach either by physical or chemical filtration of the air inhaled, or by complete isolation from the surrounding air, pure air being supplied through piping or from oxygen carried in a compressed or liquid form.

At the present time a large number of types of protecting apparatus are on the market: some of them are supposed to offer protection against all the risks together, others only against one or more of them; some are effective for an indefinite length of time, others only for a limited space of time.

Basing classification on the way in which they act (on which necessarily the efficacy of each one depends), the following categories can be distinguished:

1. Respirators acting by physical purification (filtration) of the inhaled air.
2. Anti-gas masks acting by chemical purification (to this category belong the army masks).
3. Masks with a flexible tube bringing pure air from a source situated outside the dangerous zone.
4. Self-contained breathing apparatus completely independent of the surroundings and themselves producing the air necessary for respiration.

GENERAL CHARACTERISTICS COMMON TO ALL APPARATUS

To be reliable for use, in spite of all unfavourable circumstances which can present themselves in industrial premises, all these forms of apparatus ought to conform to the following general conditions:

1. They should be strong, simple in construction and in application, and made of durable materials. They are intended to be used by men little accustomed to handle delicate articles; some of them have to be stored for a long time before they are required for use as occasion presents itself.

Despite that, they must be kept in a state of constant readiness, as otherwise they would afford a sense of false security and become a danger rather than a protection.

On the other hand they are frequently used for rescue work, notably in mines and under peculiarly difficult circumstances; the vital parts, therefore, must be protected against shock and external rubbing.

2. They should be sure to function, even in the hands of untrained or excitable persons.

3. They should be perfectly airtight in every part. Conditions 1 and 3 make it necessary to reduce to a
minimum the number of parts constructed of rubber and screw or other joints.

(4) They should have no part of the breathing circuit under a constant negative pressure which would give admission to poisonous gas or dust if the airtightness was not absolute.

(5) They should be easily worn: should not interfere with movements, nor cause any irritation of the skin at points of contact or fixation; leave the chest and arms free if possible; not make the wearer look ridiculous, because fear of ridicule accounts for so much of the opposition of workpeople towards wearing the protective appliances.

(6) They should allow of normal work without any effort or respiratory distress.

The wearer ought to be able to breathe quite freely; he ought not to feel that the air is insufficient, because then, unless particularly well trained in regard to this sensation, he will get agitated and so excited as to be led almost irrevocably to remove the apparatus.

(7) They should eliminate the requisite amount of the carbon dioxide in the expired air, thus presenting as small a dead space as possible.

The “dead space” is the volume inside the apparatus extending from the mouth of the wearer to the first valve and the contents of which, exhaled at each respiration, is filled again at the following inspiration. It ought not to be more than 250 cubic centimetres.

(8) They should be easy to maintain and inspect as well as being readily disinfected.

(9) Every apparatus equipped with a mouth-piece ought to be provided with a saliva trap and a nose clip. The saliva trap should be impossible to turn upside down, that is to say, it should not allow the external air to gain re-entry.

DIFFERENT TYPES AND THEIR CHARACTERISTICS

Respirators

Respirators are essentially mechanical filters, use of which is indicated in dusty processes.

As they are useless against fumes and poisonous gases, they can never take the place of anti-gas masks nor of breathing apparatus.

When the air contains poisonous dust in a very fine state of subdivision the respirator is insufficient as a protection, because a part of the dust can be drawn in by the air as if passes through the filtering medium. According to Winslow, this type of respirator cannot be regarded as a type that is both efficient and comfortable to wear.

In addition to the general principles laid down, a good respirator should fulfil the following conditions: it should be light and supple; permit the wearing of goggles; if possible allow the wearer to talk; present as wide a filtering surface as possible; with too small a surface for the air to pass through too rapidly and aspiration draw an excessive quantity of dust into the respirator.

In the choice of the filtering media it should be borne in mind that, even with equal porosity, all substances do not have the same property of retaining dust; some which resist the passage of air markedly allow dust to pass through readily, while others which allow the air to pass through freely stop dust well.

A simple and very effective respirator can be made of a strip of muslin about 35 cm. long and 12 to 13 cm. wide (33 x 5 ins.), using absorbent cotton wool as the filtering medium.

Respirators of this kind advantageously replace handkerchiefs, often dirty, so frequently used by workpeople who have not, or will not use, the special kind provided. They are easy and cheap to make in large quantities, and the cotton, when it becomes moist so as to interfere with breathing, can be readily replaced.

Further, and it is a remarkable fact, workpeople show the least repugnance to these improvised means.

The respirators on the market are generally composed of a mask covering the nose, mouth and chin, attached to the neck and top of the head with elastic bands in which is inserted, in front of the mouth, the filtering medium. Some masks cover the face of the wearer and include goggles. Some are provided with one or two valves. They all look when worn rather like a snout and this is one of the reasons why they are regarded with disfavour by the workpeople. Other objections are that they do not always adapt themselves to the face, are not quite airtight, increase perspiration which they do not absorb and so are inclined to set up irritation of the skin; they
hinder chewing, talking and spitting, and are not always supplied in sufficient number to provide each worker with an individual mask for his sole use.

The durability of a respirator is limited to that of the filter. When this is covered with dust so as to occlude most of the pores, it becomes unusable and must be replaced. The wearer knows when this occurs by the difficulty of breathing, taste, and the smell of the air inhaled. As this does not take place all at once, there is time enough to change it without inconvenience.

**Anti-Gas Masks**

These are filters acting at the same time both mechanically and chemically, or sometimes only mechanically. In this latter capacity they belong to the category of respirators. Certain gases when mixed with air have the property of being retained like fine dust (without the intervention of any chemical action) by filtering materials which allow the air to pass. This fact can be explained by the vibratory movements of the gaseous molecules in suspension in the air, movements so rapid that they allow of the contact of molecules with the walls of the pores during the very short time the air is passing through the filters. If a filtering material of very spongy surface be chosen, a veritable aspiration and fixation of the gaseous molecules takes place. The prototype of this material is wood charcoal usually employed in apparatus protecting against organic vapours. In the case of gases very readily acted on addition is made of chemical substances to the filters which convert the gases into harmless compounds.

Finally, use of appropriate catalysers causes oxidation at ordinary temperatures of certain gases as, e.g. carbon monoxide which otherwise only oxidises at a high temperature. When oxidised these gases become, if not harmless, at any rate less toxic or rendered capable of neutralisation subsequently by chemical reaction.

In the case of some vapours the time taken in passing through a filter, when compared with that of a breath, is insufficient to fix the molecules. It is possible in such cases to use filters the amount of air contained in which

| TABLE I. — PROTECTIVE APPARATUS FOR THE RESPIRATORY TRACT |
| Filters for Anti-Gas Masks |

<table>
<thead>
<tr>
<th>Nature of the gas to be absorbed</th>
<th>Composition of the filtering medium</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Acid gases</strong> (carbon dioxide, chlorine, formic acid, hydrochloric acid, hydrocyanic acid, hydrogen sulphide, nitrogen peroxide, phosphorus, sulphur dioxide) in average concentrations of 1 per cent. and a maximum of 2 per cent. in the air.</td>
<td>Granules of pumice-stone coated with caustic soda.</td>
</tr>
<tr>
<td><strong>B. Organic vapours</strong> (acetone, alcohol, aniline, benzene, carbon bisulphide, carbon tetrachloride, chloroform, ether formaldehyde, gasoline and petroleum, and toluene distillates and homologues) at an average concentration of 2 per cent. and maximum of 5 per cent. in the air.</td>
<td>Activated dry wood charcoal in granules.</td>
</tr>
<tr>
<td><strong>C. Ammonia</strong> in a maximum concentration of 3 per cent. in the air.</td>
<td>Copper sulphate in &quot;silica gel&quot; with cotton wool as a filter.</td>
</tr>
<tr>
<td><strong>D. Carbon monoxide</strong> in a maximum percentage of 3 per cent. in the air.</td>
<td>&quot;Hopcalite&quot; or a mixture of iodic anhydride and sulphuric acid followed by oxydite.</td>
</tr>
<tr>
<td><strong>E. Smoke, dust, vapour.</strong></td>
<td>Cotton wool.</td>
</tr>
<tr>
<td><strong>F. Acid gases and organic vapours</strong> (combination of A and B in the same concentrations).</td>
<td>Granules of pumice-stone coated with caustic soda and dry activated charcoal.</td>
</tr>
<tr>
<td><strong>G. Several of the above gases.</strong></td>
<td>A combination of the corresponding filters.</td>
</tr>
<tr>
<td><strong>H. All the above gases.</strong> Universal mask. The total concentration should not exceed the lowest maximum concentrations of the different gases.</td>
<td>Combinations of the absorbents stated.</td>
</tr>
</tbody>
</table>
TABLE II. — PROTECTIVE APPARATUS FOR THE RESPIRATORY TRACT

Characteristics of Some Self-Contained Breathing Apparatus

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Connection with mouth</th>
<th>Supply of oxygen</th>
<th>Method of oxygen feed</th>
<th>Kind of regulator</th>
<th>Concentration of the air in CO₂ after 2 hrs. wear</th>
<th>Difference between the temperature of the air breathed and that of the air outside maximum in °C</th>
<th>Total internal resistance</th>
<th>Capacity of breathing bag</th>
<th>Weight</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>FENZY</td>
<td>Mouth piece and nose clip</td>
<td>Regulated</td>
<td>180</td>
<td>Automatic; as lungs require, with arrangement for relief</td>
<td>NaOH (100-200 gr.)</td>
<td>Trace</td>
<td>Trace</td>
<td>15°C</td>
<td>85 litres</td>
<td>3.200</td>
</tr>
<tr>
<td>TISSOT</td>
<td>—</td>
<td>—</td>
<td>2</td>
<td>Supply regulated at the wish of the wearer</td>
<td>KOH</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>15</td>
</tr>
<tr>
<td>PROTO</td>
<td>Mouth piece with nose clip or mask</td>
<td>—</td>
<td>120</td>
<td>Fixed rate of supply, with emergency by-pass</td>
<td>NaOH</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>14.5</td>
</tr>
<tr>
<td>BRIGGS</td>
<td>Mouth piece and nose clip</td>
<td>—</td>
<td>120</td>
<td>Supply at fixed rate, with emergency by-pass</td>
<td>NaOH 1 K. 180</td>
<td>—</td>
<td>10-18</td>
<td>—</td>
<td>6</td>
<td>16.5</td>
</tr>
<tr>
<td>GIBBS</td>
<td>—</td>
<td>35 c.c.</td>
<td>135</td>
<td>Automatic; as lungs require, with arrangement for relief and by-pass</td>
<td>Cardioxide</td>
<td>0.75%/0.25%/</td>
<td>0.75%</td>
<td>0.25%</td>
<td>1/2 C</td>
<td>1/2 inch water pressure gauge</td>
</tr>
<tr>
<td>PAUL</td>
<td>—</td>
<td>2</td>
<td>150</td>
<td>Automatic; as lungs require, with relief and by-pass</td>
<td>NaOH</td>
<td>1.5%</td>
<td>—</td>
<td>5°C</td>
<td>—</td>
<td>10-11</td>
</tr>
<tr>
<td>INAMBAD</td>
<td>Mask or mouth piece with nose clip or goggles</td>
<td>—</td>
<td>135</td>
<td>Permanent or automatic supply, as desired</td>
<td>Interchangeable</td>
<td>0.1%/0.05%/</td>
<td>0.1%/0.05%/</td>
<td>—</td>
<td>2 cm.</td>
<td>8</td>
</tr>
<tr>
<td>McCAS</td>
<td>Mouth piece and nose clip</td>
<td>35 c.c. 1.8 to 1.9</td>
<td>135</td>
<td>Automatic; as lungs require, with relief and by-pass</td>
<td>Cardioxide</td>
<td>1%/0.7%/</td>
<td>1%/0.7%</td>
<td>16°C</td>
<td>9°C</td>
<td>1/2 inch water pressure gauge</td>
</tr>
<tr>
<td>DRAUERS</td>
<td>—</td>
<td>2</td>
<td>150</td>
<td>Supply rate fixed at 2.4 litres per minute, with emergency supply or automatic supply as lungs require and supplementary supply for safety. Arrangement for relief</td>
<td>KOH</td>
<td>0.65</td>
<td>0.91</td>
<td>12</td>
<td>—</td>
<td>10 m.</td>
</tr>
</tbody>
</table>
### TABLE III. — PROTECTIVE APPARATUS FOR THE RESPIRATORY TRACT

**Standard Conditions for Testing Filtering Canisters against Gas**

<table>
<thead>
<tr>
<th>Type</th>
<th>Number of canisters tested</th>
<th>Nature of gas and concentration in the air</th>
<th>Relative humidity</th>
<th>Temperature</th>
<th>Supply of the gas</th>
<th>Minimum life required of each canister</th>
<th>Characteristics indicating end of effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. (Acid gases)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a)</td>
<td>Chlorine 5%</td>
<td>50%</td>
<td>25°C</td>
<td>32 litres per minute</td>
<td>20 minutes</td>
<td>As soon as the air coming through the canister contains 5 per 1000 of the gas.</td>
<td></td>
</tr>
<tr>
<td>(b)</td>
<td>Hydrocyanic acid 5%</td>
<td>50%</td>
<td>25°C</td>
<td>32 litres per minute</td>
<td>20 minutes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c)</td>
<td>Sulphur dioxide 5%</td>
<td>50%</td>
<td>25°C</td>
<td>32 litres per minute</td>
<td>20 minutes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Organic vapours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Carbon tetrachloride 5%</td>
<td>50%</td>
<td>25°C</td>
<td>32 litres per minute</td>
<td>20 minutes</td>
<td>As soon as the air coming through the canister contains traces of hydrochloric acid.</td>
<td></td>
</tr>
<tr>
<td>C. (Ammonia)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ammonia 2%</td>
<td>50%</td>
<td>25°C</td>
<td>32 litres per minute</td>
<td>20 minutes</td>
<td>As soon as the air leaving the canister contains 0.10 per cent. of ammonia.</td>
<td></td>
</tr>
<tr>
<td>D. (Carbon monoxide)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a)</td>
<td>CO 1%</td>
<td>50%</td>
<td>25°C</td>
<td>32 litres per minute</td>
<td>4 hours</td>
<td>As soon as the total quantity of CO passed through the canister contains of a uniform current of air of 0.50 per cent. concentration during 1 hour (that is, about 1 litre).</td>
<td></td>
</tr>
<tr>
<td>(b)</td>
<td>CO 1%</td>
<td>50%</td>
<td>0°C</td>
<td>32 litres per minute</td>
<td>1 hour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. 1st class (Dusts, fumes, smoke, very fine particles)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tobacco smoke</td>
<td></td>
<td></td>
<td>65 litres per minute</td>
<td>5 minutes</td>
<td>Duration of the test</td>
<td>The canister should keep back at least 95 per cent. of the tobacco smoke at the end of the fifth minute.</td>
</tr>
<tr>
<td>F. (other special gases taken individually)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Smoke from cotton in a room about 28 cubic metres filled with smoke produced by burning one pound of cotton wool.</td>
<td></td>
<td></td>
<td>65 litres per minute</td>
<td>10 minutes</td>
<td>Duration of the test</td>
<td>The men should feel no irritation in the respiratory passages or eyes.</td>
</tr>
<tr>
<td>From burning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Room about 28 cubic metres capacity; atmosphere containing 0.5% of fumes of tin tetrachloride. Two men outside the room breathe the atmosphere through the canister.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The men ought to detect no irritation of the respiratory passages.</td>
</tr>
</tbody>
</table>

**Conditions of efficiency**

- The canister should keep back at least 95 per cent. of the tobacco smoke at the end of the fifth minute.
- The canister should keep back at least 50 per cent. of the tobacco smoke at the end of the fifth minute.
- The men should feel no irritation in the respiratory passages or eyes.

**Tests similar to the above modified as required.**

- AB, AC, etc. (combinations of gases).
- Must satisfy separately the tests for each one of the gases in the combination.

**H. Universal canister.**

- The canisters are tested under the same conditions as the types A, B, C, D, and E and should last the same time as each of these types separately.
is equivalent to an average inspiratory effort and the mask is equipped with automatic valves. The expired air does not pass through the filter, but is emitted directly to the outside. The air to be inspired remains in the filter during expiration; the time thus gained may suffice to precipitate the toxic molecules.

Anti-gas masks can only be used on the express condition that the surrounding air contains, after passing through the filter, sufficient oxygen (at least 16 per cent.), a condition also necessary for respirators.

This can be put to the proof by means of a lighted safety lamp. The life of an anti-gas mask is limited by that of the filter.

If this is purely mechanical the life depends on the capacity for absorption of the wood charcoal or other filtration material; if it is chemical it depends on the amount of the quantity of the reagent used. If it is a question of catalytic action the life, theoretically unlimited, is limited by the fact that the catalysers, all of which are hygroscopic, become inactive when they are saturated with moisture.

In every case, however, the exhaustion of the filters is gradual, thus allowing the wearer of the mask to become aware of the fact in time by the taste or smell of the air breathed. For gases without taste or smell such as carbon monoxide a method of indicating when exhaustion is approaching is necessary.

Anti-gas masks essentially consist of:

(a) the mask properly so-called, analogous to that of respirators sold on the market with protection for the eyes;
(b) the filtering medium fixed directly to the mask or separated from it;
(c) possibly a flexible tube connecting the filter to the mask;
(d) valves.

These masks, as is well known, can be equipped with filtering material active against one or several gases, and even against all of them. With an equal volume the filter will obviously not last so long in the latter case. When the atmosphere necessitating the use of masks is constantly vitiated by the same gas or the same series of gases, it is preferable to get the kind of filter specially designed for the particular gases or gases, omitting the others. If, in certain industries, more than one kind of canister filter has to be kept in readiness, every precaution must be taken to make a mistake impossible in choosing the right one for a given purpose. The simplest way of securing this is to paint the different canisters in different colours. If this plan were adopted an international standardisation of all colours to be used would be necessary. To protect against carbon monoxide by means of a canister filter use is made in the United States of a catalyser ("Hopcalite") which is a mixture of copper oxide, manganese dioxide, and sometimes of silver and cobalt. On contact with the oxide the carbon monoxide in the air is oxidised with carbon dioxide. A type of mask, styled "Universal", for protection against all kinds of gases and fumes present in the air is the "All-Service Mask" tested by the Mine Safety Appliances Company of Pittsburg, Pa., and approved (No. 1403) by the Bureau of Mines in July 1924. The gases and fumes pass through successively the following series of substances: activated wood charcoal impregnated with copper sulphate; wood charcoal activated but not impregnated; cotton wool contained in a metal frame: anhydrous calcium chloride; "Hopcalite" (a mixture specially prepared of copper oxide and manganese dioxide); anhydrous calcium chloride: cotton wool in a metallic frame.

This type of mask would offer protection against the following toxic gases:

(a) Acid gases (such as chlorine, formic acid, hydrocyanic acid, sulphur dioxide), by chemical reaction with the caustic soda.

(b) Organic vapours (such as acetone, aniline, benzene, chloroform, formaldehyde, petrol, etc.), by absorption in the impregnated layer of wood charcoal and by the same unimpregnated material.

(c) Ammonia, by absorption in the layer of charcoal, and reaction with the copper sulphate.

(d) Carbon monoxide, by oxidation with the oxygen of the air which is converted into carbon dioxide as a result of the catalytic effect of the "Hopcalite".

(e) Smoke, mists, dusts, etc., by the filtering action of cotton wool.

Chloride of calcium is inserted to eliminate the water vapour present in the air due to the catalytic action of the hopcalite.
In France the G. C. canister utilizes not a catalyst but a reagent, a mixture of iodic anhydride and sulphuric acid disposed superficially on a granular support. The reaction liberates iodine; at the end of the first reaction oxolith gives a hint when exhaustion is near.

The life of the two types of canister is limited, and neither taste nor smell is formed, which fixes the iodine and carbon dioxide and furnishes at the same time oxygen to prevent the vitiation of air in the canister.

It is desirable, therefore, failing a certain indicator, to adopt a given time for its use below at least 50 per cent. of the theoretic life of each canister.
Further, even this precaution only confers absolute safety in the case of new canisters or those kept in storage under vigilant supervision, away from moisture which is greatly to be feared if it reaches even a moderate degree both catalyst and reagent are rendered inert.

Thus it is seen that the use of anti-gas masks against carbon monoxide, in their present state of manufacture, have to conform to very severe restrictions not always capable of being complied with under the local conditions where they are most needed (mines and blast furnaces, etc.). Table I enumerates the various gases and the corresponding canisters to be used as protection against them. The combination of various filtering media may enable polyvalent masks to be employed suitable under the most varied circumstances.

Anti-gas masks are efficacious, simple, light, convenient, and are not much in the way. Their storage and preservation is generally easy, provided some elementary precautions are observed. They do not contain any delicate parts and their use only requires brief instructions and training of the personnel.

These canisters, however, just as in the case of respirators, cannot be used in an atmosphere saturated with toxic gases.

Their life is practically limited by the life of the filtering medium since replacing one that has become exhausted can hardly ever be effected except in fresh air.

When gases are present having neither taste nor smell, exhaustion of the canister, which is not readily appreciated constitutes a danger. Experiments with canister respirators of German and English make have also been conducted in the Netherlands (see the Inspectors of Factories Report for 1924, page 287).

**Masks with Flexible Piping (Hose Pipe) Extending to Fresh Air Outside**

This form of apparatus isolates the wearer completely from the surrounding air and connects him, by means of a flexible tube, with a source of pure air some distance away.

They are usually worked with a mechanical bellows or blower arrangement so as to overcome internal resistance in the piping which would be difficult to overcome by mere aspiration from the lungs. To pump air in is really not necessary, provided the length of the piping is not more than 30 metres, with an internal diameter of at least two centimetres.

The apparatus consists essentially of a mask with goggles and valves, a flexible pipe connected at one end with the mask, and at the other with the air intake or bellows. The length of the piping may reach 100 metres.

When several pieces of piping are joined up end to end, special care must be taken to avoid any chance disconnection.

This apparatus enables the wearer to penetrate into any atmosphere, however poor it may be in oxygen. The life is unlimited, they are simple to maintain, and easy to look after; there are very few delicate parts and they can be used with very slight previous instruction.

Their good working can be guaranteed without the need for entry into the vitiated atmosphere.

Work people like them better than any other kind of breathing apparatus.

Their range of action, however, is limited by the length of the piping which, if more than 10 metres, becomes cumbersome and hinders the workman at his job.

**Self-Contained Oxygen Breathing Apparatus**

The necessity of penetrating vitiated atmospheres, where neither anti-gas masks nor flexible piping apparatus would suffice, has led to the invention of apparatus which will completely isolate the wearer from the surrounding atmosphere and themselves provide the means of respiration.

Of such apparatus there are several types, but they all depend on the same principle; to provide a respiratory circuit independent of the external air, placing in series the lungs and a purifier or regenerator which removes the carbonic acid gas expired. This circuit is connected at the one end with a breathing bag, and at the other with a bottle of compressed oxygen which provides the expired air deprived of its carbon dioxide content with the necessary amount of oxygen.

Apart from details of construction the difference between the various types of apparatus consists essentially in the manner in which the oxygen feed is arranged.

Thus distinction is made between:

1. apparatus in which the feed is automatically and solely regulated by the call made by the lungs;
(2) apparatus with a constant feed with or without additional supply directly under the control of the wearer;

(3) apparatus where the two kinds of feed are combined.

The first method which would appear to be the most logical requires the use of very pure oxygen (99 per cent.) under pain of exposing the wearer of the apparatus to the danger of excess of nitrogen because this gas is not absorbed either by the lungs or the purifier. If it is present in the oxygen it must remain in the circuit of the apparatus and finally accumulates to such an extent as to occupy the whole of the space, thus rendering the air irrespirable. As it is impossible to find commercial oxygen sufficiently pure, it is necessary to flush out con-

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Fig. 20 - "McCaa" Breathing Apparatus (Bureau of Mines, Department of Commerce, U.S.A.).
BREATHING APPARATUS

9

The second procedure does not seem so apt, providing as it actually does a constant supply of oxygen for the requirements of breathing which are essentially variable. Thus it comes about that if the consumption of the wearer is less than the supply a certain amount must be lost irretrievably, and if the amount is more than he has an insufficient supply of oxygen and finds his breathing immediately embarrassed and himself obliged to renounce his effort. This might result in very serious consequences if, for example, mine rescue work was in question. This defect is got over by doubling the fixed quota by means placed under the control of the wearer. He must thus intervene himself to increase the supply of oxygen as soon as he feels he wants it, which is a tiresome matter for him to do just at the moment, perhaps, when, without any resistance, the slightest hindrance, he should be devoting all his energy and his two hands to the work before him.

Some apparatus carry an "injector" or nozzle with an orifice of capillary size through which oxygen from the bottle is discharged into the circuit. The suction produced by this escape of oxygen makes a narrow orifice increases the circulation of air in the apparatus, assists in overcoming internal resistance, and reduces the work thrown on the lungs. But the device is not to be recommended because it offers two grave objections: it creates a permanent negative pressure in a part of the circuit and it gets choked up easily.

In apparatus of the third kind the feed, regulated by the requirements of the lungs, only comes into play when the fixed quota becomes insufficient.

Apart from the aforementioned considerations the self-contained breathing apparatus ought to conform to the following particular requirements:

(1) The quantity of oxygen furnished ought always to correspond with the needs of the wearer, and the total quantity necessary ought always to be at his disposal. The reducing valve in connection with the cylinders for a constant supply ought to be regulated for a minimum supply of two litres a minute.

Apparatus supplying oxygen at a fixed rate ought to be provided with relief valve allowing an additional supply at the wish of the wearer. Such a by-pass is necessary on all apparatus.

In apparatus supplying automatically the quantity the lungs require, the supply ought to adapt itself immediately to the wearer's needs.

(2) The purifying substance should absorb the carbon dioxide from the expired air so completely that the air inhaled should never contain more than 2 per cent. The average percentage during a two hours' employment should not exceed one per cent.

(3) The respiratory surface should have nothing in it to interfere with free breathing; the whole internal resistance should not exceed 50 mm. of water.

(4) The temperature of the inhaled air should not exceed by 20° C. that of the temperature outside.

(5) The minimum life, without recharging, should be two hours.

(6) The weight of the complete apparatus when ready to be worn should not exceed 20 kg. It should be as light around and durable construction will permit.

(7) Apparatus with automatic supply to suit the respiratory demands ought to be provided with a relief device to prevent excess of nitrogen in the air breathed.

(8) Every apparatus ought to be provided with a manometer showing all the time the pressure of oxygen and the time it will last. The valve controlling the supply of oxygen to the pressure gauge ought to be readily under the control of the wearer and independent of the respiratory circuit.

(9) The main valve of the oxygen cylinders ought to be able to be fixed in an open position so that the wearer cannot shut it off entirely and in such a way that it cannot become accidently closed.

(10) The oxygen should be present to the extent of 96 per cent., contain no hydrogen, not more than 2 per cent. nitrogen, and with traces only of argon.

(11) The total minimum capacity of the breathing bags should be 5 litres when in one compartment and 8 litres when in two.

For apparatus intended to be used in the presence of petrol vapours or fumes from a gas generator, the following supplementary condition applies: the rubberised lining of the breathing bag is permeable to such fumes, and the protection afforded will not last for two hours unless the thickness of the layer of rubber is at least one-sixteenth of an inch (about 1.5 mm.). This minimum
should therefore be observed strictly. Apparatus which does not fulfil this condition ought not to be used for more than ten minutes, and the breathing bag afterwards aerated for a day — an operation to be affected after every occasion on which the apparatus has been used for no matter how long or short a period.

A self-contained oxygen breathing apparatus enables any atmosphere to be entered irrespective of how poor in oxygen it may be. Such appliances have a wide range of action; they enable a man to remain away from a respirable atmosphere for a period of three hours at a maximum, the distance being limited only by the life of the apparatus. But their construction is complicated and sometimes delicate, so that in spite of every care in manufacture their action is somewhat fortuitous. They require careful upkeep and selected and well-trained personnel. As they are almost exclusively used for rescue work in mines, objections to their use can be overcome by centralising all the material equipment and personnel in centralised rescue stations for mining districts. At these stations selection and training of the rescue parties can be suitably conducted, and maintenance and verification of the apparatus properly supervised.

Apparatus Supplied by Liquid Oxygen

In Great Britain use of two or three kinds of liquid-air apparatus provided with purifying material has been approved by the Mines Department. The advantages claimed for this type over those acting by compressed oxygen are the freshness of the air and the lightness of the apparatus. But they necessitate stations for the liquefaction of the air either at the mine itself or at the rescue station. Their use therefore is justified where liquid air is used for other purposes.

Such apparatus ought to allow of increase or diminution of the rapidity of evaporation, fixation of the oxygen by an absorbent to avoid waste when the receptacle is reversed, warming to a sufficient temperature the air produced by evaporation, prevention of excess of pressure in the breathing bag and elimination of impurities from the oxygen. Table II shows the characteristics of some of these forms of apparatus actually in use in different countries.

Choice of Apparatus

The following principles should be observed in choosing protective appliances:
(1) Secure separately protection against each risk anticipated, and do not attempt to combine in one and the same apparatus protection against several different risks, unless all of them should be present simultaneously in the same working area.

(2) Efficiency and safety being equal give the preference to the apparatus the least complicated in construction and the easiest to maintain in good condition.

The advantages and disadvantages described in the case of different makes will readily suggest the right type to choose.

RECEPTION AND CONTROL

When any apparatus is received it should undergo detailed testing to see if it conforms to the general and particular conditions enumerated above and if it provides complete protection under the circumstances in which it is to be used.

The best way to test an apparatus is to put it on and then to carry out methodically work of varied intensity during the period of time for which it has been guaranteed by the maker. In this way good indication can be obtained of the fitting, internal resistance, ease of respiration, freedom of movement and (for self-contained oxygen apparatus) of the oxygen supply and neutralisation of the carbonic acid gas. This test, general enough in the case of respirators, does not suffice for the other kinds of apparatus. Here examination of the diagram supplied and theoretical study of the respiratory circuit will reveal whether the general and particular conditions described above have been realised, and then detailed examination of the apparatus and all its constituent parts will show on subsequent tests whether all the other conditions have been fulfilled.

This examination will be directed spe-
comfort in wearing the apparatus (how the pieces fit to the face, ease in breathing, freedom of movement).

To test under pressure close all the openings except the breathing tubes, connect the expiratory tube to a water pressure gauge and aspirate until a negative pressure of 20 to 25 cm. of water is recorded; close this tube by a clip. Airtightness may be regarded as good if the negative pressure does not go down by more than two cm. of water in half an hour.

For apparatus of the last three types airtightness can also be verified in a gas chamber containing an atmosphere of 1 per cent. sulphur dioxide in which two men practise wearing the apparatus.

Resistance to breathing can be measured by a water pressure gauge with branch to the breathing circuit.

For a circulation of air of 85 litres per minute the total resistance in canister respirators and respirators with flexible tubing ought not to exceed 150 mm.; the resistance of the filtering medium alone should not exceed 100 mm.

In self-contained oxygen breathing apparatus the total internal resistance should not exceed 50 mm.

**Test of the Filtering Material**

This test requires to be done under exact laboratory conditions.

For respirators and anti-gas masks it will suffice, after having put the mask on carefully, to close the orifice for entry of air, with the palm of the hand, and aspirate deeply; the vacuum created in the apparatus makes the mask stick to the face of the wearer. If it is quite airtight it should keep so for at least fifteen seconds.

In the case of respirators with flexible tubing depending on pure air supply outside the vitiated atmosphere, the test for airtightness is less important if use is made of a bellows or blower fan.

For self-contained oxygen breathing apparatus the test should be carried out under pressure or under a negative pressure, but the thing to test for is airtightness against negative pressure. To test under pressure close the free ends of the breathing tubes and close the safety valve of the bag, allow oxygen to flow in, let the breathing bag fill, then close the inlet for oxygen, put pressure on the bag with the hand and if this resists and does not empty airtightness is good.

**Fig. 2a. — Diagram of a self-contained oxygen breathing apparatus:**

- E = Mouthpiece.
- O = Oxygen bottle.
- R = Regenerator.
- S = Breathing bag.

**Test for Airtightness**

The different filtering materials may be classified in eight categories:

**Type A.** Acid gases, such as: carbon dioxide, chlorine, phosgene, sulphur dioxide, etc.

**Type B.** Organic vapours, such as: acetone, alcohol, benzine, carbon bisulphide, carbon tetra-chloride, etc.
Type C. — Ammonia.
Type D. — Carbon monoxide.
Type E. — Dusts, fumes, and smoke.
Type F. — Other special gases taken individually.
Type AB, AC, etc. — Combinations of two or more of the preceding types.
Type H or Universal. — Combination of all the preceding types.

The conditions of the efficiency test differ according to the type of the filtering medium. Table III gives the standard conditions laid down by the United States Bureau of Mines, which can be taken as a guide.

To verify the chemical stability two of the canisters are subjected to each of the following tests:

(a) Pass through the filter, at the rate of 64 litres a minute for six hours at room temperature, air free of carbon dioxide, and with 25 per cent. relative humidity. Let the canisters be then submitted to the efficiency test, which ought to give a life of at least 10 minutes.

(b) Carry out the same test with air containing 85 per cent. relative humidity. It is a good plan to subject the canister to a severe test at maximum concentration; the passage through it a current of air containing 1 per cent. of the gas at the rate of 64 litres a minute, the other conditions of the test being for humidity: 50 per cent.; gas used: for type A, phosgene; for type B, carbon tetrachloride; for types C, D, E, the special gas in question; for the polyvalent canisters, several of the above gases.

Concentration: 1 per cent. in volume; number of canisters tested: 2 for each gas.

The life of the canister ought to be five minutes at least for every gas except carbon monoxide, which should be at least 15 minutes.

Test of the Supply of Air or Oxygen

For apparatus with flexible tubing test is made as to whether the bellows or blower fan can supply at least 60 to 70 litres a minute. The wearer of the mask ought to be able to breathe without trouble through the bellows at rest.

To test the supply available in self-contained oxygen breathing apparatus, it is sufficient if the feed is fixed at a definite rate, and the capacity of the breathing bag is known, to determine by means of a stop-watch the time it takes to get filled; what is actually found should correspond to the claim made by the maker.

If the feed is worked automatically, then the relief valve for the automatic release of oxygen is inspected to see if it is performing its work properly when the breathing bag reaches the limit stated by the maker. The working of the safety supply and relief must next be tested.

The supply of oxygen ought to allow an average consumption of 2 litres per minute.

To last two hours the cylinder ought to contain at least 1.6 litres under 150 atmospheres or 2 litres under 120 atmospheres.

Testing the Purifying Substance

Verification is best made in the first instance by weighing, and if necessary by chemical test of the power of absorption of the regenerating material, bearing in mind that it ought to last 50 per cent. longer than the cylinder of oxygen.

The mean respiratory quotient should be taken as equal to 1, that is to say, the average relation of the quantity of oxygen inhaled to the quantity of carbonic acid gas exhaled. For a total consumption of 240 litres of oxygen as much as 240 plus 50 per cent., that is, 360 litres of carbon dioxide should be taken or 16.2 molecules of this gas.

But the fixation of the molecule necessitates:

47 grm. of lime (Ca(OH)$_2$) or 80 grms. of soda (Na$_2$OH) or 112 grm. of potash ($KOH$).

The mass, therefore, necessary is then about 1,200, 1,300, or 1,800 grms., according as whether lime, soda, or potash is used.

Regeneration, however, becomes insufficient as soon as the carbonation reaches 70 per cent. in the case of the solid absorbent and 100 per cent. in that of the liquid. Supposing that the absorbent solutions are in a concentration of 50 per cent. that is to say, equal weights of the water and the base, the weight of the regenerating substance should be about:

1,700 grms. in the case of lime.
1,800 grms. solid soda.
9,500 grms. of soda.
9,600 grms. solution of soda.
3,600 grms. solution of potash.

These weights are pretty high; they can be reduced proportionately as the margin of safety, put at 50 per cent. in relation to the oxygen supply is exceeded.

Obviously verification by weight ought to be made, in the case of liquid absorbents, pari passu with verification of the concentration. The chemical test can be made in the same way as an ordinary analysis of carbon dioxide. Either the total quantity of carbon dioxide absorbed can be determined or the time during which the absorbent material remains effective. 75 litres per minute of air, containing 4 per cent. carbon dioxide being made to pass through in a continuous stream.

The total quantity absorbed ought to be at least 240 litres and the duration of effectiveness at least two hours. The tests may be considered to be ended as soon as the air leaving the regenerator contains 2.5 per cent. of carbon dioxide. The average concentration for the whole duration:
of the test ought not to be more than 1 per cent.

All these tests may be usefully completed, except in the case of simple respirators, by a very complete practical test, either inside, or outside, the gas chamber — a test, therefore, giving information as to the fitting qualities, the ease of breathing, and freedom of movement. It would confirm other tests notably those as to air tightness, efficiency and life.

Storage and Maintenance of the Apparatus

Storage

A place out of the sun, free from dust, acid vapours (especially sulphurous gases), high or low temperatures, and damp should be selected.

All rubber parts ought to be kept in a dark, damp room. A good place to keep them is in a double-walled zinc cupboard where a cup containing petrol, or a ball of cotton-wool soaked in petrol, is kept. If risk of fire is feared, water may take the place of petrol. This procedure is especially applicable in the case of spare parts. It is not to be thought of in connection with apparatus that ought always to be in perfect condition ready for immediate use. These are best dealt with by smearing vaseline on all the rubber parts.

Anti-gas masks ought to be stored in the cases supplied by the makers, and the canisters ought to be protected by means of tampons and corks against every possible penetration of air. The same is the case with the purifying material for self-contained oxygen apparatus.

In replacing the apparatus in their cases or boxes every care ought to be taken to avoid all kinking of the masks or flexible tubing.

Maintenance — Periodical Examination

If the measures for storage are well arranged, their maintenance will reduce itself to a monthly inspection of each apparatus in detail by someone of experience (made responsible for the work) and the replacing of any parts that may have deteriorated or got worn out.

After Use

Care should be taken to replace immediately all parts that have been used up — filtering, canister, re-generating material, oxygen cylinders, and all defective pieces.

The masks should be cleaned with a moist linen cloth and left to dry before placing them back in their cases.

The mouthpiece and connecting pipe should be disinfected using a disinfectant which does not attack any part of the apparatus: e.g. a solution of perchloride of mercury 1 in 4,000, or 2 per cent. Lysol apparatus: e.g. a solution of perchloride which does not attack any part of the should he disinfected using a disinfectant placing them back in their cases.

Moist linen cloth and left immediately all parts that have been used up: the measures for storage are well arranged, their maintenance will reduce itself to a monthly inspection of each apparatus in detail by someone of experience (made responsible for the work) and the replacing of any parts that may have deteriorated or got worn out.

For apparatus which includes a breathing bag, disinfection of the bag is done by exposure to formalin vapour for an hour, or by immersion in one of the solutions named. If the latter is done, the bag should be dried slowly and carefully for from 12 to 15 hours.

It is advisable to seal the cases and boxes containing the protective appliances.

Use of the Apparatus

Use of the protective appliances calls for certain precautions under pain of unpleasant, sometimes fatal, experiences.

Defective, badly fitting, or wrongly used appliances are much the more dangerous in that the wearing of them induces a false sense of security. Thus it should be a sine qua non when they are about to be worn to examine them most carefully and have them rapidly tested. The personnel called on to use them should be methodically trained to fit them perfectly and to use them rationally under the most difficult circumstances imaginable.

The examination of respirators should extend to their state of cleanliness and the way in which the filtering medium is fixed, how the mask fits the face, and the way the valves, where such exist, work (see above).

For canister anti-gas masks the examination should include: the state of the seal on the case; the nature and state of the canister (care especially should be taken to see if the corks have been properly inserted); the way the mask fits the face and the airtightness as in the case of the respirators; the valves and connections between the canister and the face-piece should be submitted to strict inspection.

Anti-gas masks require a little training by the persons likely to use them. Masks with flexible tubing require to have the face-piece examined (as above) and also the tubing, the connections, and the bellows or blower fan. The wearer should try breathing through the apparatus without setting the latter in motion. The test for airtightness is made as in the case of anti-gas masks, but by closing the orifice for the air entry into the bellows.

For self-contained oxygen breathing apparatus, rapid testing must be done on the external parts (pipes, bands, breathing bag, face-piece, or buccal attachment and its connections), and the airtightness must also be tested. It is necessary to close all the openings and blow down the expiratory pipe; when the whole apparatus is full of
air a further blowing up should be impossible.

To test if it is under negative pressure: negative pressure should be brought about by aspiration until the walls of the bag are quite close together: they ought to remain in this condition for five minutes after aspiration has ceased. The oxygen supply should be verified in the same way as when such apparatus is received; the amount of oxygen should be determined by simple reading of the manometer, and the regenerating substance tested as when received omitting the chemical test.

Use of self-contained oxygen breathing apparatus requires a highly trained personnel. The United States Bureau of Mines has published an excellent code of directions on this subject based on the experience gained at rescue stations.

In the case of all safety apparatus the wearer, completely equipped, should practise a few exercises for about five minutes before entering the poisonous atmosphere.

**Legislation**

Generally respirators are required by law to be supplied to all workmen exposed to the risk of inhalation of poisonous gases, vapours and dusts. These masks, supplied by the employer, must be maintained, washed and cleaned daily, and renewed when necessary.

When poisonous substances are in question the filtering material must be washed, cleaned or renewed once a week. Respirators must not be left in the workroom; a responsible person should be in charge of them.

In regard to breathing apparatus, especially that intended for mine rescue work, tunnels, chemical industries, etc., the regulations laid down are more stringent. They cannot be reproduced here in detail (see the *Legislative Series* published by the International Labour Office).

Generally speaking the Regulations require the apparatus (breathing and oxygen apparatus) to be examined once a month by a competent person familiar with their use, and the results of the examination to be entered in a register kept for the purpose, and to be shown to the inspector on demand.

The Chemical Section of the National Safety Council of the United States has proposed the adoption of a series of colours to distinguish the canisters with special filtering material against different gases. The standard list is as follows:

<table>
<thead>
<tr>
<th>Colour</th>
<th>Filtering material</th>
<th>Causes of danger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>Activated wood charcoal.</td>
<td>Organic vapours and fumes.</td>
</tr>
<tr>
<td>White</td>
<td>Soda lime.</td>
<td>Acid gases and vapours.</td>
</tr>
<tr>
<td>Yellow</td>
<td>Activated wood charcoal and soda lime.</td>
<td>Mixture of organic vapours and acids.</td>
</tr>
<tr>
<td>Yellow stripes</td>
<td>Activated wood charcoal, soda lime, and cloth filter.</td>
<td>Mixture of acid and organic vapours and smoke.</td>
</tr>
<tr>
<td>Green</td>
<td>Sulphate of copper on granules of pumice.</td>
<td>Ammonia.</td>
</tr>
<tr>
<td>Brown</td>
<td>Sulphate of copper, activated wood charcoal, and cloth filter.</td>
<td>Ammonia and smoke.</td>
</tr>
<tr>
<td>Grey</td>
<td>Hopcalite, calcium chloride, and caustic soda.</td>
<td>Carbon monoxide.</td>
</tr>
<tr>
<td>Red</td>
<td>Wood charcoal, sulphate of copper, calcium chloride, &quot;Hopcalite&quot;, and cloth filter.</td>
<td>The majority of gases, vapours, and fumes (polyvalent canister).</td>
</tr>
<tr>
<td>Blue</td>
<td>Caustic soda (impregnation).</td>
<td>Hydrocyanic acid.</td>
</tr>
</tbody>
</table>

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Breweries


The production of beer — a fermented drink prepared with malt or germinated barley and flavoured with hops — was formerly carried on in a great number of small factories. Nowadays, the tendency is, at any rate partially, to concentrate manufacture more and more in large establishments in which very modern equipment permits of a larger production as well as a notable improvement in the hygienic conditions of the persons employed.

Initial Substances

Initial substances include barley that has begun to germinate, or malt and hops, yeast, ice and water. Other initial substances are sometimes employed instead of barley. In some countries use is made of other cereals or, as substitutes, glucose and treacle. For hops other bitter products have been substituted and these substitutes are the result of local custom or of fraud on the proper character of the beer. They may exercise an influence on the health of the consumer and at times on that of the workmen, as when use is made of glucose obtained from acids not arsenic free.

Industrial Operations

The manufacture of beer comprises the following processes:

(a) Preparation of the malt (Mälzerei);
(b) Preparation of the hops (bleaching with sulphur);
(c) Preparation of the wort or mash;
(d) Decoction and addition of the hops;
(e) Cooling of the wort;
(f) Fermentation of the wort;
(g) Racking and filling of casks and complementary fermentation;
(h) Bottling;
(i) Maintenance of the barrels.

(a) Preparation of the malt, or malting. Malting or malt manufacture on a large scale (French: malterie. — German: Mälzerei or Maltfabrik. — Italian: fabbrica di malto. — Spanish: fabrica de malto) is quite separate from the brewery, constituting sometimes a special industry.

The preparation consists in placing the barley under conditions favourable for its germination and interrupting this at the moment when the malt contains the maximum of substances capable of entering into the composition of the wort.

The first process is the sorting and cleaning of the barley, then follows steeping which is carried out in tanks called cisterns and lasts for from 48 to 108 hours according to the nature and age of the grain. In the process of steeping the grain absorbs 40 to 50 per cent. of water, but loses about 2 per cent. of substances which are dissolved out of it. Carbon dioxide is given off in the operation, and the water, which is at first coloured brown, has to be renewed.

The steeping makes germination possible, and during its course the maximum transformation of the nitrogenous material into diastase is achieved.

The germination, or malting, takes place in the malthouse in semi-darkness. The wet barley is spread out on the floor of the malthouse in layers 12 to 15 cm. in thickness. It is turned over
at first every 6 hours, then every 8 hours, until it appears dry. When germination becomes general the area of the floor covered is reduced to one half, so that the layers become of a thickness of 25 to 30 cm. The temperature rises. Much water vapour condenses on the upper layers (sweating). Much carbon dioxide is given off and also certain ethers emitting a special odour. The layers are turned, their thickness is reduced so as to lower the temperature when germination is sufficiently advanced, that is, when the radicles exceed by about a quarter the length of the grain and the felting of the grain is normal.

The duration of germination varies according to season and climate. The barley loses about 7 per cent. of its weight. To avoid hand labour during germination, pneumatic malting has been substituted with the special object of trying to eliminate the carbon dioxide which is prejudicial to germination and to hinder and prevent overheating the grain. There are many systems of this pneumatic malting.

The grain coming from the malthouse (green malt) is carried to the kiln, and placed on the floor in a thick layer of 3 to 5 cm. It is turned 6 or 7 times a day. When dry the radicles are removed, some separating from the grain themselves, others are removed by machine. Complete separation is effected by a winnowing machine.

For the manufacture of certain beers, this air-dried malt suffices; but in the great majority of cases it is submitted to a kind of roasting more or less pronounced in an apparatus known as a malt-kiln.

The malt-kiln consists of two parts: that on which the grain is spread out, and that where the heat is produced for curing and roasting. Malt-kilns are of two kinds: smoke-kilns and hot-air kilns. In the former curing is done with the aid of the mixed gases and air coming directly from the combustion of the fire. In the hot-air malt-kiln, the curing is done by means of air and does not contain any of the fire gases. The grain is stirred from time to time by the aid of tools introduced through lateral openings. Malt-kilns are also constructed in which the grain is stirred mechanically.

Drying is done at first at a temperature of from 90 to 90° C. then at 50° up to 70° C. The degree of curing varies according as the desire is to produce a pale or high dried malt.

The malt-kiln only accentuates and completes the transformation commenced by germination. In order to colour certain beers, the malt is roasted over a naked flame in sheet metal cylinders like coffee.

Good malt ought to yield on extraction at least 70 per cent. of its dry weight.

(b) Preparation of the hops. — The hops used for the manufacture of beer consist of the female flower of the plant (Humulus lupulus). This flower which is in the form of strobiles or cones contains different substances having an action universally recognised and appreciated. It gives to the beer a special aroma; it retards the alcoholic fermentation and hinders considerably other fermentations in the wort.

The quality of the hops exercises a considerable influence on the delicacy of the flavour of the beer and on its stability. They must be gathered in favourable weather and must be dried properly so as to avoid their becoming mouldy.

Drying is effected either on screens in the open air or in the oast-house. Frequently, in order still further to preserve them, the hops are sulphured, that is, exposed to sulphur vapour. One to 2 kg. of sulphur are needed for 100 kg. of hops.

Sulphuring the hops, followed by exposure in the oast-house to a moderate temperature, or slight impregnation with a small quantity of alcohol, compression and preservation in a place hermetically closed, are the means adopted to preserve them.

The hops dried at a temperature of about 40° C. are subjected to strong pressure and are despatched done up in watertight pockets or bags. The world's production of hops is about 95,000 tons.

(c) Preparation of the wort. — Under the name of wort or mash is understood the liquor containing the solution of the products of the malt with the addition of what this liquid has been able to extract from the hops with which it has been in contact. The fermented wort becomes beer.

The preparation comprises: the crushing of the malt, mashing, decoction and addition of hops, and cooling.

The crushing, which must not be pushed too far, is intended to facilitate the solvent action of water. The mashing enables the maltose and dextrine to be extracted from the malt and increases the amount of this maltose and dextrine by the action of the diastase on the starch in presence of water. Similarly, it allows of the
production of peptone and para-peptone as a result of the action of peptone on the proteid substances. Washing is preceded by preliminary soaking to prevent unduly strong action of the hot water on the malt.

The mash is then carried to a suitable temperature to ensure saccharification. This is done either by infusion or decoction.

The first method is known as top fermentation and is employed in a great part of Northern Germany, in France, the United States, Canada, Great Britain, Belgium, and in some places in Central Europe. The second is known as bottom fermentation and is customary in a great number of breweries of Europe and especially in breweries yielding Bavarian, Viennese or Pilsener beers.

Whether done by infusion or boiling the work is carried on in special rooms which is the brewery so called (Sudhaus in German) with an equipment consisting of mash tuns, large copper in which either the infusion or decoction of the malt is effected with variations depending on the taste of the consumer.

The temperature of the liquid during the mash is from 45 to 70°C.

The residue after the malt is exhausted is called grains.

In certain countries glucose is added to the wort thus obtained in order to increase its richness. Glucose made with diastase should be used rather than glucose made with sulphuric acid which might contain traces of arsenic. Treacle is sometimes added.

(d) Boiling and addition of hops. — Boiling has for its object the concentration of the wort, solution of the ingredients of the hops, and coagulation of a part of the proteid matters, and precipitation by the tannin in the hops of the starch which has so far not been transformed. Boiling clarifies the wort and frees it of the substances which would hinder the preservation of the beer. The action of the temperature is reinforced by the addition of the hops, the effect of which is not only to give the beer a special flavour, but also to introduce into the wort substances aiding in its clarification, in the progress more or less rapid of fermentation, and in the preservation of the manufactured beer.

The hops are added after boiling has brought about coagulation of certain substances which must be extracted from the wort.

(e) Cooling the wort. — Cooling the wort must be carried out as quickly as possible to avoid the production of lactic acid between 25° and 30° C.

Cooling takes place either in the open air in huge vessels called coolers, or in making the wort circulate over refrigerating pipes, or by a combination of the two methods.

The temperature to which the wort is reduced depends on that of the locality where the fermentation is carried out and on the nature of the latter.

(f) Fermentation of the wort. — After having been cooled, the wort is ready to undergo alcoholic fermentation.

Depending on the temperature to which the wort has been brought or that prevailing in the fermenting room, on the quantity and kind of yeast, on the time, more or less long, taken, on the quantity and quality of the hops added, fermentation is carried out in two ways: bottom fermentation, and top fermentation. Lager beers are prepared by bottom fermentation.

In this kind of fermentation the wort is placed in large vessels (gyle vats) placed in cellars where the temperature in from 4° to 5° C. The yeast having been put in, the temperature of the wort has a tendency to rise during the principal fermentation (2,500 calories per 100 litre of beer containing 3° to 5° of alcohol). The liquid in the vat is cooled by means of floats containing ice or by a coil of pipes through which a solution of chloride of calcium at 2° to 3° C. circulates.

The principal fermentation lasts nine to ten days for lager beers and from 7 to 8 days for beers intended for immediate consumption.

The fermented wort is given the name of green beer and is placed in barrels which have been specially prepared to undergo a complementary fermentation. The temperature of the cellar must not exceed 1° or 2° C. in order that the secondary fermentation may be effected slowly.

The ice consumed in cooling the wort and for keeping down the temperature in the cellars amounts to 20 to 50 kg. per hectolitre of beer. The barrels, before they are placed on the market, are filled quite full for some days in order to increase the quantity of carbonic acid in solution.

Top fermentation is practised in Belgium, England, Northern France, Alsace, Bohemia, etc. The beers so produced do not keep so long as beers of bottom fermentation, but they are lighter and produce more of a head.

The fermenting vats are of large diameter and the addition of the yeast
is done at 12-15°C. — sometimes more (white Berlin beer). The principal fermentation lasts between three and four days. The secondary fermentation is carried out in casks, as in the case of beers of bottom fermentation, or in bottles.

Cooperage. — The cooperage constitutes an important part of the whole brewery. To prevent the beer penetrating into the wood with the consequent inconvenient result of setting up fermentations other than alcoholic, when the casks are empty (and also to avoid leakage) the inside of the barrels are coated with pitch or an alcoholic varnish. This coating of pitch or varnish has to be frequently renewed after the removal of the old one. In the cooperage also an important number of repairs are carried out on the casks and barrels.

The coating of the casks by means of pitch is done either directly or by hot air or steam. The operation is dangerous because of the risk of fire or explosion, the vapour given off from the pitch forming an explosive mixture with air.

Dangers

In small breweries the same workmen may carry out all the necessary processes, but in the large breweries the various operations are entrusted to different groups. The workmen, therefore, in small factories are more exposed to brusque changes of temperature than in the large, and consequently more liable to be affected by chills.

Electricity is coming more and more into use, permitting as it does of the substitution for hand labour, always arduous, of mechanical means for carrying out the different operations of raking of "the goods", mashing, washing the filters, tarring and washing the barrels, manipulating the blocks of ice, bottle washing, and labelling, etc., and especially of conveyance of sacks and barrels.

Without stressing too much the heavy work in the store-rooms of the malt-house or brewery, reference should be made as regards the first class to the injurious effect of the atmosphere charged with dust and carbon dioxide and especially to the high degree of humidity. The men are obliged to work with little clothing; they are continually mopping away sweat which is at the same time saturating the little clothing they wear. All this favours chills. Work in the kilns exposes to the action of a humid atmosphere as far as the second and third stages and to one extremely hot towards the end of the operation (62-99°C.), temperatures which excite great thirst. The same arduous labour is met with during the removal of the rootlets from the malt (at 40 to 45°C.) unless this is done mechanically.

Manipulation of the barley before germination gives off a considerable quantity of dust which is not easy to eliminate; the same unpleasantness is met with on the second (lower) platform of the oast-house when the grain is turned (shovelling) unless this is affected mechanically.

In brewing the workmen are exposed to the same dangers as those in the malt house — hot, humid, and cold air (fermenting chambers artificially chilled to 3-4°C. and to an atmosphere rich in carbon dioxide according to the type of plant (kilns with direct firing).

So far as the chronic effect of prolonged inhalation of high proportions of carbon dioxide (see that article) is concerned it must be admitted that it has not yet been accurately determined. Lehmann and his pupils, Brickel and Herrlighoffer, have shown that proportions of 0.5 to 2.0 per cent. by volume in the air cause no specially marked symptoms in the persons working in the fermenting rooms. Though the contrary may have been observed in the past, it is to-day exceptional.

Danger of asphyxia has been reported among workers, especially in the cleaning of the fermenting vessels; thus, for example, in Great Britain, in 1913, three such cases were reported in breweries; in 1914, 1 (fatal); in 1918, 1 (fatal); in 1919, 1 (fatal); in 1921, 2 (both fatal); in 1923, 3 non-fatal cases. The sulphuring of the hops, whether done directly or by burning the sulphur, involves risk of gassing by sulphur dioxide, as also will escape of this gas from the coils of the (sulphur dioxide) refrigerating apparatus. The same danger is present near an ammonia freezing apparatus when pipes break or joints are imperfect, etc.

Use of disinfectants and preservatives, such as, e.g., hydrofluosilicic acid (H₂SiF₆), called in Germany "Montanin", often impure from silieic acid, oxide of iron and zinc, etc., can also set up poisoning. In Prussia (1919) use of "Antiformin" for cleaning caused cases of poisoning (it consisted of a resin dissolved in a mixture of pyridine, acetone, etc.).

In the Netherlands cleaning the hop back with a solution of nitric acid
caused three cases of poisoning in 1919 (escape of nitrous fumes).

Use of methyl alcohol (see this article) as a solvent for painting the barrels and vats has caused in America (New York, Buffalo, Chicago, etc.) severe cases of poisoning (blindness). In the same country (Ohio) attention has been drawn to the possibility of lead poisoning from putting the capsules on the bottles, and in Austria (1914) from use of colours with a basis of red lead to mark the barrels. In Great Britain in 1914 a fatality was caused by the use of a paint containing trichlorethyrene.

The tarring of the barrels, especially when done by hand, exposes to the fumes given off from the melted pitch. (See article Tar.) When done on a large scale use is made of special apparatus with steam jet and absorption of the fumes, but all such apparatus are not free from imperfections. Finally sulphuretted hydrogen is given off from the decomposition of the residual waters (as in all industries employing organic substances).

STATISTICS

The statistics of sickness insurance societies, especially in Germany, show that the morbidity among brewery or malt house workers reaches that of the most unhealthy industries. Westergaard has even expressed the opinion that such morbidity is only attained in industries where a special danger exists, such as lead poisoning or inhalation of dust.

It must in fairness be said, however, that brewery workers and maltsters run considerable risk of accident, and it is not always easy from these statistics (Germany) to distinguish between incapacity from illness and that from accident.

Nevertheless, the following are the figures furnished by the sickness insurance societies of the brewers and maltsters of Berlin, Dresden, Kottbus, Mannheim, Schoeneberg-Berlin, Strassburg, Stuttgart, and Leipzig. The data of Sommerfeld are taken from the reports of the sickness insurance societies of the brewers and maltsters of Berlin only, and those of Backert from the Society of Brewers of Berlin, covering 25,000 cases of sickness, and of Dortmund where 1,450 were registered.

These different statistics show that diseases of the locomotor system and rheumatism are those that affect this class of worker most (about 20 cases per 100 members; 16.5 per cent. of the cases of sickness). Next come diseases of the respiratory tract (about 15 cases per 100 members; from 6-12 per cent. of cases of sickness). Gastric troubles and infectious diseases show also high morbidity rates from 7 to 10 cases per 100 members; from 7 to 9 per cent. of the cases of illness); very frequently accidents show a percentage of 16 to 20.

According to the statistics of the local sickness insurance society of Leipzig, the group (maltsters and brewers) had 25 days of sickness per 100 insured and only 15 days per 100 insured at the group aged 25 to 34 years, which would permit the deduction to be made that the unhealthy-ness of the trade is felt in later years. Though according to this experience tuberculosis and respiratory diseases show an average below that for other trades, and diseases of the digestive tract are about the same, diseases of the locomotor system are, on the other hand, very numerous as well as lesions (accidents) affecting it.

The general morbidity rate was 45 per 100 workmen in this group as compared with 40 per 100 in all the groups. Thus the relative value was as 1.16 to 0.77 per 100 workmen. Occupational poisoning is unknown. As regards rheumatism and diseases of the locomotor system, when compared with other industries, brewers show very high figures of morbidity: for Stuttgart, for instance, a percentage (per 100 members) of 21.69 as compared with 16.49 for other occupations, 20.09 for Berlin as compared with 14.54; and 13.17 for Leipzig as against 7.8 was revealed.

Villaret has described a peculiar lesion of the nails due to the action of the yeast. (As regards alcoholism, see later.)

An enquiry conducted in the State of Ohio in 1914-1915 by Hayhurst and extending to 11 malthouses employing 1,055 men did not yield information of special interest. He recalls, however, that the American Brewers' Trade Union had had notified to them in 1913, 732 deaths among its 42,218 members, that is, a mortality of nearly 17.34 per 1,000 caused mainly by tuberculosis (22.81 per cent.), respiratory diseases (11.88), heart diseases (10 per cent.), diseases of the kidneys and liver, etc. (4.78 per cent.). Fatal accidents showed a percentage of 13.16 and suicides 4.10 per cent. Grouped according to age the relative figures per 100 deaths were as follows:

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 20 years</td>
<td>0.96</td>
</tr>
<tr>
<td>From 21-30 years</td>
<td>10.79</td>
</tr>
<tr>
<td>From 31-40</td>
<td>19.26</td>
</tr>
<tr>
<td>From 41-50</td>
<td>33.30</td>
</tr>
<tr>
<td>From 51-60</td>
<td>69.00</td>
</tr>
</tbody>
</table>

According to Backert the mortality among the Austrian union of brewery workers was as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Death Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1910</td>
<td>1911</td>
</tr>
<tr>
<td>201</td>
<td>208</td>
</tr>
</tbody>
</table>

Number of deaths of members From deaths of members 301 298 332 345 Per 100 deaths From tuberculosis 38.3 29.8 22.2 30.7 respiratory diseases 8.0 11.4 12.6 digestive diseases 11.4 5.6 6.6 3.1 circulatory diseases 3.0 18.4 16.5 17.3 accidents 6.0 10.0 12.3 11.0

Westergaard (1901) has quoted Tatham's figures concerning English brewery workers and has reproduced the following table:
For every 1,000 persons at the following ages there died annually:

<table>
<thead>
<tr>
<th>Age-Groups</th>
<th>Brewers</th>
<th>All-occupied males</th>
<th>General population</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-25</td>
<td>35-45</td>
<td>45-55</td>
<td>55-65</td>
</tr>
<tr>
<td>Malsters</td>
<td>4.69</td>
<td>11.18</td>
<td>18.13</td>
</tr>
<tr>
<td>Brewers</td>
<td>10.83</td>
<td>19.04</td>
<td>30.79</td>
</tr>
<tr>
<td>General population of the district</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occupied males</td>
<td>8.65</td>
<td>15.91</td>
<td>27.82</td>
</tr>
<tr>
<td>General population</td>
<td>7.67</td>
<td>13.01</td>
<td>21.37</td>
</tr>
</tbody>
</table>

For every 1,000 persons of all who died in the general male population 1,427 brewery workers died from the following causes:

- **Diseases of the liver**
- **Diseases of respiratory system**
- **Diseases of nervous system**
- **Alcoholism**
- **Phthisis**

The comparative mortality figure represents that maltsters and brewers run particular risk from changes in temperature and alcoholism. As regards temperature, the occupation upon a sample of the general male population enumerated at the Census of 1901, which showed 1,000 deaths.

Pathology

The above figures show that maltsters and brewers run particular risk from changes in temperature and alcoholism. As regards temperature, the description of the processes has shown that work in the malt-kiln is done in 70-80° C., that in the mash room it mostly varies from 15-20° C. and is sometimes even higher, and that, in the fermenting room, the temperature varies from 1-5° C.; in these workrooms the humidity rate is very high. For as the workmen employed ordinarily outside the brewery — draymen, carriers, etc. — they are exposed to the weather.

A very general custom in breweries is to allow the workmen free consumption of beer. In North Germany this reaches about 5 litres per day per worker; in South Germany 8 litres.

In a Lyons brewery the management had fixed 5 litres per day as the quantity to be distributed to the workmen. It was given up because of the pilfering resulting from this limitation which would react by favouring the frequency of diseases of the digestive organs brought on by ingestion of large quantities of cold liquor.

In some countries the draymen are frequently given drinks in the course of their rounds, not of beer, which they consume like their mates at the brewery, but of alcohol, glasses of which are taken at the counter at the moment of delivery.

In bottling breakages are pretty frequent and entail accidents to the fingers, face, eyes, etc. — a frequency especially prevalent among the persons employed in the store department and cooperage (transport of barrels, unless this is done mechanically).

Hygiene and Prophylaxis

Floors should be of flagstones or asphalt; use should be made of enclosed apparatus, ventilated or provided with efficient exhaust hoods especially over the boilers. There should be sufficient ventilation in the boiling and fermenting houses to reduce the humidity. Hand labour should be replaced wherever possible by mechanical devices as this much improves the health conditions in certain departments for the preparation of malt and beer.

In regard to temperature it is evident that work in the malt-kiln is unpleasant; nevertheless the workmen have to go in there in order to turn over the malt and to watch the effect of the heat. Almost universally hand
labour in malthouse work has now been replaced by machinery, and for recording the temperature of the malt in the apparatus devices exist by means of which this can be done from the outside.

The moist heat in the malthouse and in the brewery proper is very unpleasant from the health point of view, but it can be largely mitigated by efficient ventilation. Lack of movement in the presence of warm, moist air makes it all the more trying (see article "Warm and Moist Air").

The above remarks apply also to the oat-house and when sulphuring is practised; work should be so arranged that no one should enter the apparatus before it has been sufficiently cooled nor until the air has been sufficiently freed of sulphur dioxide by adequate ventilation.

It is most important to take measures to render asphyxiation impossible in the rooms and in connection with apparatus giving off carbon dioxide; malthouse, fermenting vats and cellars. Not a year passes without record of some such case in factory inspectors' reports. When carbon dioxide is produced with its tendency to collect low down, mechanical ventilation must be instituted. Entering fermenting vats and apparatus should be prohibited whether it be for cleaning them or for any reason whatever, until they have first been adequately ventilated.

To guard against escape of ammonia the pipes and joints must be closely watched, and masks or, better still, breathing apparatus constantly available. Precautions should be taken when sulphur or sulphur dioxide is used. Sulphur should be burned in metallic boxes and precautions taken to avoid dispersion of the fumes as well as to avoid gassing or premature entry into the sulphuring chamber. Useful purpose is served by exposing moist litmus paper which should not become pink. If fans are installed it should be remembered that iron is attacked by the acid gas and rapidly destroyed. They should be of earthenware. Ozone or electrified air assists normal fermentation of the wort and hinders parasitic action. The process is widely applied at the present time.

Ozone also serves to disinfect the filtering material, the chips, the apparatus, the piping (except india-rubber) and also for ventilation, particularly of the refrigerating plant (instead of filtering the air through cotton wool), the vats, cellars, bottles, etc. This system rationally applied in all stages of the manufacture permits of obtaining a product which renders pasteurisation unnecessary. Combustibles giving rise to black, thick, prolonged smoke should be avoided; the residues and waste in the precincts and workrooms should not be allowed to accumulate for more than a day; everything should be kept as clean as possible.

It must be admitted that purification of the residuary water rich in putrefactive organic substances, which can readily become acid by biological means, offers certain difficulty. Their mixture with some of the residuary waters of dwelling houses helps in maintaining a slight alkaline reaction. Preliminary decantation of the detritus and insoluble material must be secured before biological purification which should be followed by the addition of sufficient milk of lime to prevent fermentation of the organic matters. The process has not, however, been perfected so far.

To prevent alcoholism among the workmen the practice of allowing them to consume beer ad libitum should be discontinued. The danger from dust is less to be feared from the point of view of its action on the respiratory tract than from that of accident. Several explosions have been reported due to the fact that accidentally the dust produced in the grinding of the malt becomes overheated. Substitution of an alcohol varnish for that of pitch is scarcely to be recommended on the score of health; the alcohol used being almost always either methyl alcohol or wood spirit of which the injurious action on the sight is well known; this action is the more to be feared because the alcohol vapour, before dissipating in the workroom, escapes in large volume from the casks by the sole means of issue — the bunghole near to which the workman is obliged to keep his face in order to observe what is going on inside.

**LEGISLATION**

There is no special legislation relative to the manufacture of beer.

**BIBLIOGRAPHY**


At the present time the sulphuric acid is almost always replaced by hydrochloric acid and the manganese dioxide by the hypochlorite or chlorate of magnesium. This modification of the process permits of the recovery of magnesium chloride, which is a valuable by-product.

The extraction is very often carried out by means of chlorine gas. The mother-liquor trickles through a tower filled with stone, or through a tower with trays, traversed by an ascending current of chlorine. The vapour of bromine which comes off is collected in a cooled worm, the non-condensable vapours being retained by iron fillings, with which they form chloride of iron.

Before the war the industrial production of bromine was confined to Germany, where it represented a secondary industry connected with the salt industry. During the war, France organised the extraction of bromine from the mother-liquor of the salt marshes of Zarzis in Tunis. Recently the ever-increasing demand for bromine for the manufacture of tetra-ethyl lead and chiefly of ethylene dibromide, with which the tetra is used in commerce, has driven technical experts to seek out other sources and to have recourse to direct extraction of bromine from sea water. Bromine is then set at liberty by chlorine; the small quantities of free bromine are combined with aniline, and tribromaniline so obtained is collected on filter presses.

Moreschi has recently (1926) extracted bromine from the mother-liquor of a salt marsh by the use of chlorine. But he withdraws the bromine in a continuous manner by the use of a solvent — the tetrachloride of carbon — and then makes powdered hydrate of calcium act upon the solution obtained. He thus obtains a special bromide of lime which yields all its bromine in a free state by the simple action of dilute acids.

Crude bromine, which contains from 2 to 5 per cent. of chlorine, should be purified by distillation in glass retorts either alone or in the presence of bromides of potassium, of iron, or of calcium. Refined bromine still contains about 0.3 per cent. of chlorine, whilst chemically pure bromine contains traces of organic combinations of bromine.

Uses

Bromine is conveyed in the liquid state in glass bottles, or in the form of "solid bromine", which consists of
"Kieselguhr" (the remains of extinct diatomaceous) in the form of flour, after it has absorbed about 75 per cent. of bromine and has been moulded into the form of small sticks.

Bromine is used, either in the liquid state or in the form of gas, as a disinfectant: in laboratories as an oxidiser, often in the state of bromine water, an aqueous solution of which is preferred to chlorine on account of being easier to use; in gold and platinum metallurgy for extraction and purification; in medicine; in photography; in the production of artificial colouring matter, such as eosine, indigo bromide, of wood alcohol, and of asphyxiating and lachrymatory gases, such as bromide of benzyle, xylene, mono- and dibromacetone, bromo-methyl-acetone, bromopiricine, and bromocyanogen; in the preparation of Prussian blue and permanganate of potash.

Bromine is generally packed in large, blue glass bottles, carefully closed with ground stoppers and sealed. The bottles are placed in wooden or metal boxes filled with ashes or sand or "Kieselguhr".

**Sources of Dangers**

Every escape of gas or dust containing bromine represents a danger risk to the mucous membranes and skin. Accidents are quite common, although not as a rule, serious, in laboratories and factories where bromine is used. The manipulation of compounds of bromine used for asphyxiating gas is very dangerous. The risk of explosion at normal temperatures or at a slight heat when bromine comes in contact with phosphorus must be provided for. Danger from asphyxia by certain compounds of bromine must also be borne in mind, for example, in the manufacture of indigo when using bromide of xylene.

**Toxic Action**

Lehmann in 1887 by experiments on animals demonstrated the actual toxicity of this metalloid, the action of which is similar to that of iodine. This authority noticed that bromine vapour set up, among animals, a strong, irritating action on the respiratory and digestive passages, giving rise to numerous severe haemorrhages, from the surface of the gastric mucous membrane, for example, which are not caused by chlorine; and also that it exerted a solvent action on the hair of the body and head, which it turns yellow. A given volume of bromide gas acts in the same way as the same volume of chlorine gas, but by weight bromine is two and a half times less toxic than chlorine. According to Lehmann, however, experiments made upon men with very small doses have proved that the absorption of bromine is complete.

Bromine gas on the skin causes a feeling of heat, a yellowish staining, and some more or less pronounced congestion. If the action is of short duration, vesicles and pustules are reported to appear; if of long duration, ulcers appear which are painful, deep, and difficult to heal.

When inhaled the gas causes dyspnoea with a feeling of suffocation; these effects are extremely painful even with minute quantities.

This irritant and caustic action on the respiratory passages favours the development of such diseases as bronchitis and broncho-pneumonia.

Marino in 1919 studied experimentally the action of bromine gas on the blood. He found that it diminishes both the number of blood cells and the quantity of haemoglobin, and that this diminution is more marked in proportion as the quantity of vapour is increased; but it is not increased consequent upon repeated inhalations. On the contrary, some immunity is established so that the doses have to be increased if it is desired to get the same results as before. With small continued doses, bromine causes haemolysis and pronounced leucocytosis (about four times the normal) acting chiefly on the lymphocytes, and also, strange to say, on the neutrophile leucocytes when the gas acts in large doses and over a long period.

Pellegrini has found in animals that died in consequence of inhaling bromine vapour intense pulmonary oedema and serious lesions of the bronchi. If death occurs at the end of some days, foci of broncho-pneumonia are found. The alveoli are filled with oedematous fluid, rich in halogen combinations, rather than being affected by the direct action of the poisonous gas. Moreover, the respiratory apparatus is the path by which halogen compounds are eliminated when thrown off by other organs, and it suffers from circulatory troubles caused by asphyxiation.

No facts are available relating to chronic poisoning; nor to acquired immunity to bromine. It seems, however, that workmen are not affected by chronic forms.

Some experts, on the contrary, speak of an anaemic state which appears to be due to the chronic action of bromine.
The poisonous doses are not well known. Lehmann found that a dose of 5.5 c.c. per litre of air is quickly fatal or very dangerous to cats; that a dose of 0.22 to 0.33 acting during thirty to sixty minutes is dangerous, but not fatal; that a dose of 0.022 per litre during a similar period does not cause serious symptoms, and, finally, that a dose of 0.007 to 0.014 for six hours does not cause serious symptoms. However, according to some experts bromine does not give rise to methaemoglobinuria. Bromine introduced into the system is eliminated in the form of alkaline bromides by the urine or in other organic secretions.

**Symptoms**

In addition to local lesions on the skin and mucous membranes considered above, and troubles caused by the inhalation of the vapour, bromine generally causes acne, which was observed by Oppenheimer in 1915 among workmen who made asphyxiating gas bombs. The faces of these workmen were slightly oedematous, especially the eyelids, which were also the seat of discharging pustules and became rapidly covered with crusts. The acne also covered the cheeks and forehead, but rarely the neck.

Like the other halogens, bromine makes the teeth turn yellowish, causes conjunctivitis and even keratitis, as well as rhinitis and more or less severe stomatitis. In serious cases, bromine may cause troubles of sensation, with diminution or even an absence of conjunctival reflex, as well as troubles of vision.

A case of idiosyncrasy has also been noted in a student of Professor Bunge who had worked in the laboratory with bromine water under an exhaust hood. He showed violent irritation of the conjunctiva which did not affect his fellow-workers.

It should be said, however, that cases of poisoning of occupational origin by bromine are comparatively rare, when its frequent use is taken into account.

Among the compounds of bromine must be mentioned ethyl bromide (C₂H₅Br) obtained by the reaction of bromide and phosphorus on alcohol, or of neutral sulphate of ethyl on a boiling aqueous solution of potassium bromide. This compound causes, by its vapour, cough, headache, vertigo, and even loss of consciousness. Fortunately, in consequence of its rapid elimination from the system, it only gives rise to transitory symptoms.

For methyl bromide, see that article. The other compounds, used as explosives or as asphyxiating gas, are naturally violent irritants of the mucous membranes.

**Detection**

Free bromine is easily recognised by its smell. It can be isolated by distillation with sulphuric acid and manganese dioxide or potassium bichromate. In the urine, bromine can be detected, after having added an excess of potash, by evaporation, calcination, and shaking the residue so obtained with ether, chloroform, or carbon bisulphide. The bromine, which is isolated, can be recognised by its smell, by the colour of the solution, and by decoloration of indigo. Bromine can also be transformed into bromides or to the state of bromide of silver (see text books on toxicology).

**Hygiene**

As for all poisonous gases.

**Legislation**

As for poisonous gases. The injuries caused by bromine and bromide of ethyl are compulsorily notifiable in France and compensated as accidents in Switzerland. Cases of acute poisoning are generally grouped under the heading of industrial accidents.

### Bronzing and Bronze Manufacture


**Technology**

Bronze and brass (see article "Brass") are the most important alloys of copper. Under the name of bronze is understood generally a series of alloys characterised by their hardness, tenacity and resistance, in which copper and tin are the chief constituents. Ordinary bronzes often contain zinc or lead in small quantities, while special bronzes may contain reducing substances such as, for example, phosphorus, manganese, silicon, nickel, etc.

The copper is first melted. Bronze clippings are then added and, at the end of the operation only, some tin. The colour of the bronzes vary, chiefly according to the quantity of tin which they contain.

Industrial bronzes are of very varied composition according to the object for
which they are intended. The quantity
of copper may be said to vary between
70 and 81 per cent., and that of tin
between 4 and 11 per cent., that of lead
between 8 and 15 per cent., that of zinc
70 and 81 per cent., and that of tin
of copper may be said
which they are intended. The quantity
present very widely applied.

Ordinary kinds of bronze are utilised
in the manufacture of bells, cannons,
machines, and their numerous acces-
sory parts. They are also used for
making art bronzes (bronze for statues,
for instance, for which lead and zinc is
added, giving a softer alloy easier to
manipulate). Japanese and Chinese
bronze (very rich in lead), bronze for
making coins, medals, piping, etc.
Aluminium bronze is harder and more
resistant than copper bronze and is at
present very widely applied. It is used
for the manufacture of imitation gold
alloys, in the manufacture of jewellery,
table and kitchen ware, etc.

Bronze colours. — These are of much
greater importance from the point of
view of industrial hygiene. They are also
known under the name of "metallic
colours" or bronze powders. (French:
Bronze-couleurs; German: Bronzefarben,
Bronzepulver, Metallfarben; Italian:
Colori metallici, Bronzine; Spanish:
Colores por broncear.)

These colours are prepared from
waste from the metal industry and from
alloys reduced to very fine dust, even
microscopic flakes. In order to obtain brown shades,
the metals forming the alloy. Thus,
for example, orange bronze is got from
an alloy consisting of 89 per cent.
of copper and 1 per cent. of zinc, while
the latter two substances
are also in part due to the varying propor-
tions of copper, zinc, traces of lead,
arsenic, tin, iron, etc. — in short, of
the metals forming the alloy. Thus,
for example, orange bronze is got from
an alloy consisting of 99 per cent.
of copper and 1 per cent. of zinc, while
copper-red bronze is made of pure
copper. Silver bronze contains tin, zinc,
and aluminium in varying proportions,
while aluminium bronze consists almost
entirely of aluminium with traces of
zinc. Other coloured metallic powders,
such as rose, red, dark copper, pale
green, olive green, violet blue, are also
used for bronzing. The manufacture
of gilded or silvered bronze involves
liberation of a considerable quantity
of fine dust, even when the operations
of grinding, pulverising and drying are
affected in closed apparatus.

Gold leaf is in general an alloy of
copper and zinc rolled into thin sheets,
then hammered into still thinner sheets
and wrapped in parchment. Hammer-
ing, a noisy and tiresome operation,
is now almost universally done by
machinery. Metal leaf is used for
mouldings, frames, gilding and silver-
ing of furniture and ornaments, etc.
The gilding is applied by means of a
gum containing benzene, or benzol,
acetone, pyroxyline, wood alcohol,
amyl acetate, and ammonia (see these
articles).

Bronzing powders are used in
the lithographic and the printing indus-
tries, in mechanical printing of wall-
papers and other mural decorations,
for bronzing metallic powders, such as lamps, trays, cash boxes,
bicycles, and the stamping of pencils
and paint brushes and trade marks,
etc. They are used in leaf form in the
same way as gold by applying them by
means of special glaze or in powdered
form with thin glaze (bronze glaze).
The term "bronzing" comprises all
processes in which use is made of
metallic powder in a dry or wet state
for coating with gold, silver or bronze
a surface composed of paper, wood,
metal, leather, glass, canvas, etc.
This term is equally applicable to
other electrolytic processes used in
bronzing watch cases and other metal
articles.

Polygraphic industry (see article
"Printing Trades" for bronzing in the
lithographic industry).
Hand bronzing is still employed where the work is irregular or of slight importance. This operation is necessary in the printing of proofs which are too small in size to be put into machines, for certain types of paper (American paper), for fancy papers (thick and thin), cards and boxes, and for all work, in fact, for which the demand is too slight to justify the use of machinery.

The bronze is applied with a pad of cotton wool or of felt, or with a hare-foot brush dipped in the powder. This operation liberates much dust, especially where the workers are careless or inexperienced. The bronzed sheets are cleaned with a duster or clean pad.

**Letterpress printing.** — The printing processes are identical with those in lithographic printing, but as the sheets are usually smaller (sheets for fancy stationery) there is less machine bronzing. Bronze inks have been successfully introduced in letterpress printing, but are not suitable for rough parchment papers or for colour printing.

**Colour printing.** — This process does not involve liberation of dust and offers no risk.

**Wallpaper manufacture.** — Liquid bronze has now practically replaced dry bronze for this purpose. Hand bronzing is done in the smaller factories where block printed papers are manufactured. The powder is rubbed on with a soft brush and the paper finally dusted with a leather pad to remove the surplus bronze. For machine-printed wallpapers a more brilliant effect is said to be obtained by means of dry bronze, but in fact the difference is hardly perceptible. In dry bronzing the paper passes in course of the different processes through various closed apparatus. A little dust escapes from the grooves of the machine, but it is drawn off by exhaust ventilation. The use of liquid bronze (mixture of size and bronze powder) represents an economy by avoiding loss from use of superfluous powder.

**Metal lacquer.** — Sheets of paper and cardboard are often bronzed over the whole surface either with dry powders in bronzing machines or with liquid bronze in separating machines. If coloured metallic effects are required, hand bronzing is reverted to. Silvering and gilding are also done by hand where small fancy articles in tin, wood, leather, canvas, and glass are concerned.

**Bronzing of metal articles.** — Japanned articles and metal articles (tea trays, cycles, cash boxes, stove castings) are often decorated by means of bronze powder. Metal lamps after being covered with the bronzing powder are heated in an enamelling stove in order to set the bronze, and when cold are varnished.

Generally the workers size a certain number of articles before bronzing them. Little dust is raised, the covering of boxes with gold powder or varnish being done wet and hence not generating dust. There is likewise little production of dust in decorating japanned trays with gold leaf or gold paint which is applied with a leather rubber to the sized surface. For castings, lamps, and stoves, bronze powder mixed with spirit and copal varnish is applied either by aerograph, by a brush, or by hand where necessary. Little dust is liberated during this process.

**Bronzing of metal sheets.** — Black iron sheets are coated with aluminium by means of an ordinary cylinder bronzing machine as in printing. After bronzing, the sheets are passed through a dusting-off machine with enclosed machinery provided with well-fitting covers. There should be little escape of dust.

**Stamping on wood** (pencils, paint brushes, etc.). — Bronze powders (chiefly aluminium) are very widely used for stamping of wood by means of small automatic machines. The type is heated in a gas jet or by electricity and dusting off is effected either by machine or by hand. Little dust is produced in the process, the powder being heavier and more greasy than ordinary aluminium bronze powder.

The same process is used for the ends of paint brushes. This work, however, as well as the dusting off, is sometimes done by hand. Very small quantities of powder are used and the workers therefore do not suffer inconvenience.

**Bronzing of textile fabrics and leather.** — Liquid bronze is used for printing cotton cloth, velveteen and leather. For velveteen the dry powder mixed with starch is applied by bronzing machines. During manufacture of gold brocade materials fine metallic dust is liberated, which causes irritation of the mucous membrane of the conjunctivae.

Finally, attention should be drawn to the risk of explosion due to bronze dust.

**Pathology**

Pathology of bronze-founders is identical with that of copper- or brass-founders (see those articles). Only one case of poisoning by phosphorus is
known (due to phosphoretted bronze: reported by Kaup in an Austrian cannon factory). In this article only the pathology of workers engaged in bronzing, that is to say, workers using metallic colour, will be dealt with. The occupational risk in this category of workers is chiefly connected with inhalation over long periods of metallic particles, the injurious effects of which have been studied by Arlidge, Oliver, etc. Bronze dust is composed of angular particles similar in form to those of road metal, but which would not appear to possess such an irritant effect as the metallic dust generated in grinding metals. So far no specific damage of the respiratory tract due to this cause has been met with. It must, however, be admitted that as a rule the workers do not long remain in this industry and the work is largely intermittent, and the occurrence of more or less serious affections of the nose, upper respiratory tract (nasal catarrh, dryness of the throat, cough), referred to by Roepke and Poljak as affecting workers manufacturing and using the metallic colours, is certainly points to diminished resistance to tuberculosis.

As regards the toxic effects of these colouring agents in which copper is present to the extent of 70 to 90 per cent., it must be admitted that the danger is chiefly due to the impurities which they contain or to other substances used for bronzing (bichromates, solvents such as benzols, benzene, acetone, etc.). It is true that copper dust when it gains access to the digestive tract may set up symptoms (see article "Copper"). Zinc, which forms 30 per cent. of the powders usually employed and 77 per cent. of the silver powder, does not possess specially toxic properties (see article "Zinc"). Aluminium, which is present in these colours in small quantities, has no toxic effect.

The presence of traces of lead (according to Sternberg, 0.1, 0.2 and even 0.55 per cent.) has certainly been the cause of poisoning among workers engaged in bronzing (especially of women). The presence of traces of arsenic might also be responsible for more or less marked affections. However that may be, the dust generated during the preparation and use of these metallic colours is said, according to an authority, to have been the cause of the following symptoms: dyspnoea, vomiting, diarrhoea or constipation with colic, headaches and discomfort in the respiratory tract. A greenish line between the crown of the teeth and the gum, and often a greenish coloration of the teeth and hair and perspiration, and even nervous disorders where the worker has long been exposed to the action of the dust in question. Other authorities are, however, quite opposed to the theory which attributes these symptoms to copper or bronze. In a bronze colour factory, where the workers were coated with powder, Merkel states that no case of copper poisoning had ever occurred. He admits, however, that bronze dust is dangerous to the health, although this opinion is contrary to that expressed by the German factory inspectors when reporting upon conditions in the factories of Fürth and Nuremberg.

An English Government enquiry made by the Dangerous Trades Committee, when reporting in 1910 on bronzing in the lithographic industry, stated that the workers suffer fairly serious affections of the skin. Apart from bronzing that is to say, workers using metallic colour, will be dealt with. In hand bronzing (without provision for dust removal), when work was regular, 53 per cent. of the workers complained, and when irregular with less prolonged exposure 50 per cent. — facts which prove well the direct relation between more or less prolonged exposure to dust and the inconvenience experienced. Two groups of symptoms were noted in the enquiry: (1) nasal catarrh, dry throat, cough, slight irritation of the eyes due to dust, and (2) coppery taste in the mouth, epistaxis, nausea, sickness, headache, lassitude, anorexia, constipation or diarrhoea, with colic, and irritation of the skin due to the special nature of the dust, and liable to disappear when the worker changed his occupation. Dentists have noted swelling of the gums and pyorrhoea as well as slight stomatitis. There has also been reported a type of eczema due to the bronze powder used in chromolithography (use of bi-chromates?) and troubles caused by solvents.

In the German book-binding workshops, it was noticed in 1921 that the workers suffered from fits of coughing and very disagreeable metallic taste in the mouth due to the inhalation of bronze powder. Simon and Knuyt have, among others, drawn attention
to the risk of lead poisoning due to the use of bronzing powder containing 7 per cent. of lead, but the cases notified have been rare. The bronze powder is often present in suspension in benzene, acetone, pyroxyline, wood alcohol, amyl acetate, etc., and presents all the dangers connected with these substances (see these articles). Cases of muscular atrophy and of gastro-enteritis among workers handling bronze colours have been noted by Popoff and attributed by Casamajor to zinc, but the likelihood of this has been contested by several authors, for, as has been stated, it is generally accepted that the symptoms attributed to copper are, indeed, rather due to impurities present in the bronzing powder. The workers engaged in the manufacture of gold leaf in Vienna showed high morbidity and mortality rates from bronchitis, chronic emphysema, and tuberculosis. The morbidity rate for Austria was, according to Jehle, 42.5 as against 27.5 for workers in other industries. According to Hirt, these workers were particularly susceptible to respiratory diseases, and especially to tuberculosis.

The workers in question also incur risk of injury due to the explosion of bronze powder. Burns are in many cases localised on the hands and more especially on the interdigital space of the left hand (Ullmann).

Hygiene

Where it is impossible to ensure the installation of an effective exhaust system for dust removal, the employment of children and young persons should be prohibited on all bronzing processes. The liberation of dust during bronzing and cleaning of bronzed articles should be as far as possible prevented by the use of closed machinery provided with good exhaust apparatus. The enveloping of the joints of the cover of the machine in strips of lambs' wool is to be recommended.

The use of ventilation hoods without closed machinery, as well as that of closed machinery without an exhaust system for dust removal, gives negative results. Elimination of dust by downward suction is preferable. In chromolithographic printing good results have been obtained by a machine provided with a vacuum. The excess of the bronze powder falls through a perforated grid into a recipient placed under the machine and is drawn off by a draught into a “cyclone” separator, whence it is brought automatically to the pipe which provides the machine with bronze. When bronzing is done by hand it should be carried out on tables provided with a perforated grid and an exhaust system, or inside a box the upper part of which is covered with a flap having a space in front to allow of the worker inserting his hands and arms.

Another method is to use perforated tables with a metal grid on top and furnished with drawers in which the surplus dust escaping from the machine is collected. Dusting-off machines when separate should be provided with localised and adequate exhaust ventilation. Bronzing machines used in textile and leather factories should always be closed, provided with localised exhaust ventilation and installed in a separate workroom. The flooring of the bronzing shops should be uniform and impermeable. It should be frequently swept wet and maintained in good condition.

Wherever possible, the bronzing shop should be separate from other workshops, and should never be situated beside machinery (for instance, lithographic machines in the polygraphic industry). Workers engaged on bronzing should be suspended from work or given different work as soon as they complain of symptoms possibly due to dust inhalation. Measures of personal hygiene applicable to unhealthy trades should be enforced. In factories where bronzing is carried out on a large scale, douche baths should be installed for the use of the workers. A certain amount of time should be granted for compulsory washing before meals and prior to quitting the establishment.

In American factories respiratory masks are sometimes used (see article "Breathing Apparatus, etc."). These are in reality not very practical, are viewed with dislike by the workers, and are generally useless except in the rare event of impossibility of dust removal by means of ventilation in factories of wet processes. Working clothes and headgear, changed and washed weekly, should be placed at the disposal of the workers, who should also be provided with cloakroom accommodation.

For hygiene in bronze foundries, see articles "Copper" and "Brass".

Legislation

In Austria, the regulations of 1923 for the polygraphic industry ensure special measures in regard to bronze (see article "Printing Trades"). In France the Decree of 13 May 1893 forbids the employment of young persons under 16 years of age in bronzing factories. In Germany, special regulations dealing with bronz-
ing have been drawn up by the town of Berlin. In Great Britain, the regulations of 11 April 1912 deal with bronzing by metallic powder in the polygraphic industry and in the covering of metal leaf. In Holland the law relating to the work of women and children prohibits the employment of women and young persons in bronzing operations (Cat. B. 1), especially in the typographic and lithographic industries and the manufacture of frames (Cat. G. 10). Bronzing in the printing industry, or other occupations even where toxic bronzes are not used unless special measures are applied relating to the cubic space allowed, the height of the workrooms, etc. (section 57, 1, etc.). In Norway a Decree, dated 1920, comprises measures in regard to installation of bronzing factories in the lithographic industry. Measures drawn up in regard to brass and copper foundries are also applicable in the case of bronze foundries (see these articles).

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**BROOMS**

**(Broom Corn, Sorghum)**


Broom corn is an annual grass plant which attains a height of two to four metres, the most commonly utilised species of which is _Sorghum vulgare_ with long spikes, dark brown seeds, oval in form, and ending in a sharp point enclosed in a sheath equally pointed. Sorghum, largely used in the manufacture of brooms, represents a danger for the workers who handle it, as already observed by Ramazzini.

Sorghum is chiefly cultivated in North America, Africa, and northern Italy. The manufacture of brooms from this plant is very widely developed in Italy (north) as a domestic industry. Whole families are employed in the work, buying raw material and the tools, and selling the product of their labour to wholesalers. Factory workers engaged on this type of work are, however, also numerous, and recently factory production of this kind has made rapid strides. The preliminary operations are effected by peasants, who cut and harvest the sorghum plant at the end of summer, remove the seeds by beating each stalk or several stalks at a time above a receptacle or by passing a wooden lever over the stalks laid on the ground. These operations cause the liberation of much dust. The dried seeds are used for animal fodder. The stalks are exposed to the sun for a few days, then tied in bunches and sold to broom makers.

The _manufacture of brooms_ is carried out either as a domestic industry or in factories. In the first case, the work is effected in the peasants’ homes, almost always on a mud floor without any protection against damp. In winter the work may be carried on in stables or byres. The workroom is in general overcrowded and crammed with material. Lighting is of course very defective. The operations are similar to those effected in the factories, where in general conditions are less unhealthy than in the domestic industry, though lighting is also not infrequently defective even in the factories, which may be also overfilled with material and very dusty. Factory regulations are certainly applied, but the working day is long and the wages low. In certain districts the worker has a contract by which he is guaranteed work throughout the year.

The stalks are at first bleached during twenty-four hours in chlorine or sulphur dioxide fumes in small hermetically sealed places, then exposed to the air during a fairly long period to allow of elimination of the fumes. It most frequently happens, however, that the stalks are manipulated before this elimination has been completed. A certain number of stalks are then firmly attached to the handle of a broom by means of a metallic wire or several twisted of a thin flexible branch. This operation, effected by men, calls into play all the muscles of the body, and the effort required is considerable. A certain dexterity is also necessary. The posture required for this work is bad.

The subsequent processes, mostly effected by women, consist in binding the stalks together with a large broom wire and a firm binding medium. Women and children then fix the head of the broom on to a block and cut the ends to uniform length with a hatchet. Children chiefly are employed in sorting and dividing the stalks of sorghum, flattening them and arranging them in different sizes. They also carry stalks from one workroom to another as the processes proceed. Each of these operations raises a large quantity of dust, partly composed of the debris from the sheaths which contained the seeds. Even with the naked eye it is possible to distinguish the dust from the seeds in two points. These contain fragments of the seeds completely dried so that the dust raised is almost entirely composed of such pointed debris. With a microscope it is possible to see that the film-like substance which encloses the seeds is covered with transparent and faintly coloured spikes. Application of a few drops of sulphuric acid is followed by rapid ero-
sion and the bursting of the envelope, laying bare spikes with a hard compact surface which resist erosion possibly by reason of their silicious nature. While laboratory experiments have been able to supply the explanation of the irritant mechanical action of the dust on the skin, other research effected with the extracts to ascertain whether there exists also a toxic chemical action has been without result.

It should be recalled that this grass plant is attacked by several parasites, among others by the Bacillus sorghi, Pass, the Pyrausta nubitalis Huba, etc., and certain authorities attribute the cutaneous lesions met with among workers in the industry in question to these.

**Pathology**

The fumes of chlorine or sulphur dioxide cause irritation of the mucous membranes (respiratory and conjunctival) with coughing and lachrymation. The fumes are bitter and irritant, but, short of producing symptoms of suffocation, they cannot be said to give rise to a specific poisoning and may almost be considered as without danger.

The particles of debris with which the dust is charged cause exorciations and morbid affections of the skin, the most frequent of which is erythema. If sorghum dust be applied experimentally to the face of a man for two periods of thirty seconds each, there is caused severe hyperaemia which, however, differs in character among different individuals and even for the same individual on different parts of the body, since resistance is greater where the epidermis is thick. Prolonged friction causes erythema with slight excoriation, which lasts several hours and then disappears completely until the next application.

The erythema is often complicated by more or less diffuse eczema, generally situated on the uncovered parts of the body: forearm, neck, feet (when bare). When, however, clothes are hung in the workroom, the dust may penetrate inside these and may later attack all parts of the body. The worker affected with severe itch scratches himself and thus produces a series of sores known under the name of "broom-makers' disease", which, however, disappears once the cause is removed.

Hoffer in 1918 studied twenty-five cases of erythema affecting seven American families who had been occupied in cutting brooms. He was not, however, able to satisfy himself whether symptoms were due to the sorghum itself or to parasites inhabiting it.

The operation of fixing the end of the broom with metal wire causes the formation of a callosity situated on the palmar surface of the left forefinger. Another callosity crossing the palm of the hand is due to the pressure of the metal wire and to a deposit of oxide of iron. Bad posture, particularly during this operation (trunk bent forward and chest contracted), leads to dyspepsia and epigastric pain (contraction of the abdominal organs), often obliging workers to quit their work and engage in agricultural labour, which leads to recovery. Binding the stalks of broom with metallic thread or a flexible branch causes among women furrows due to drawing through the large needle and situated on the palm of the right hand, which is, nevertheless, protected by a piece of leather. A callosity is also formed at the point in contact with the arm on pushing it in and drawing it out. All these workers have their hands covered with sores and scratches caused by the sharp points of the broom stalks, by the fibres of the sorghum, or by the metallic wire or cutting tools.

Lachrymation due to the acid fumes is transitory and very rarely gives rise to conjunctivitis which, when present, is probably due to other factors. A simple form of conjunctival catarrh, due to the dust, is very frequent and may often become chronic. No other derangements of sight have been met with, except those which might be ascribed to bad lighting. There has also been ascribed to dust and to acid fumes the outbreak of acute cases of pharyngitis, often accompanied by complications (tonsillitis, rhinitis, laryngitis, and tracheitis). In certain cases a temperature of 38.5° to 39.5° C. and other symptoms have been met with, the effect of individual reaction to inhalation of the dust. There is often coughing, catarrh of the pharynx and larynx, dryness of the throat, intense thirst, headache, loss of appetite, exhaustion, and sometimes photophobia. Fever generally lasts twenty-four hours and gives after rest and light diet. Chronic bronchitis is rare; anaemia and pallor are often due to bad hygienic conditions, and rheumatism to work on a damp floor or to draughts. Dysmenorrhoea is common amongst women.

No statistics are available in regard to the broom-making industry, which, up to the present, has been badly organised, comprising as it does very scattered workers. It is at the present time, however, in course of rapid organisation. Observations made by a certain number of medical men justify the statement that the incidence of tuberculosis does not exceed the rate reported for other country workers.
though there may exist a slight susceptibility to irritation of the respiratory passages, favoured by unhygienic conditions, sedentary life, fatigue, and malnutrition.

**Hygiene**

Breaking machines should be placed under a hood providing for elimination of the dust from the seeds and other foreign matter. All the dusty processes should, as far as possible, be carried out mechanically. Some establishments reduce dust production by the process of breaking in a wet state. The injurious effect of acid fumes can be avoided by exposing the stalls for a sufficient period to the sun and fresh air subsequent to bleaching and prior to further manipulation.

Workers should be provided with cloakrooms and lavatories and all necessary aids to personal cleanliness. Such installations should, of course, be separated from the workroom.

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**Building Trade**


**General Observations**

This industry comprises quite a group of professions and trades involving various risks and calling for adequate precautionary measures. Without mentioning them all it will suffice to refer to the more important.

**Labourers** dig the foundations and prepare the soil by removing earth and stones or by filling up where necessary. **Masons** carry out the principal building work either in different materials (bricks, ashlaid stone, griststone, etc.) bound together with mortar, or constructed entirely of reinforced concrete. **Plasterers** carry out all the plaster work, facing and relacing the outside and inside walls, ceilings, cornices, and different decorative designs. Often (as in Paris, for example) the masons themselves do this work. **Tilers** and **slaters** cover the roofs of houses (with tiles, slates, zinc and lead sheeting, etc.). **Builders' carpenters** do the woodwork of large size — the construction and setting of such work as attics, floors, and staircases. On the other hand, it is the business of the joiners to carry out the smaller type of woodwork, either fixed (wainscotting, panelling, plinths, stairs, stair railings) or movable (frames of doors and windows). **Carriers** should be made also of *parquet floor layers* and *floor tilers*; **paper hangers**, who apply the papers to the walls with a brush, the printed papers being cut into suitable lengths and backed with paste; **decorators**, who carry out the painting work inside the houses; **plumbers**, who lay the water and gas pipes, and sometimes those for central heating; **electricians**, who do the wiring for electric lighting, and sometimes for power, etc.

**Sources of Danger**

All these operations are not attended with the same degree of risk to health.

The most important risks for masons arise mainly from work in the open air and from weather conditions, and are increased by the fact that modern technique allows of work being done in cold weather. Among other injurious factors the constant standing and the carrying of the loads must be mentioned. While means of transport and mechanical lifting are more and more used there still remains a certain number of unavoidable manipulations. Carriers of lime and stone, for example, have still sometimes to carry weights of 80-90 kg. up to the top of several stories.

The nature of the materials handled also plays an important rôle in the pathological effect produced: work in stone and cement notably gives off different dusts (see articles "Cement", "Lime", etc.).

Mention must be made of certain *special risks*: of lead poisoning among those covering the roof with lead, painters and decorators, etc.; risk of carbon monoxide poisoning among those watching over building operations when fires in open brasiers are kept going at night for speeding up the drying of the rooms (Leymann). Paper hangers are also exposed to special risks, especially when the hanging is preceded by the scraping off of old papers, which is a very dusty operation if care is not taken to wet the paper well beforehand. Sand-papering is also an extremely dusty operation. Men-
tion must be made, too, of the risk of poisoning by lead or arsenic when the papers contain these. Risk of accident, arising from work on scaffolding (fall of material, falls of workmen), must not be omitted. Severe accidents, it is true, have diminished since legislation has dealt with accident prevention, but the possibility of buildings collapsing remains, which mostly happens as the result of heavy rain on unfinished buildings; and particularly there is to be reckoned with the possibility of slight injuries, bruises and cuts, etc., giving rise to whitlows and inflammations.

**Statistics**

The statistics of the Leipzig Sickness Society give interesting information relating to the morbidity and mortality of certain groups of workers in the building industry:

**DAYS OF INCAPACITY FOR WORK FROM SICKNESS RATES RELATING TO 100 WORKMEN DURING ONE YEAR**

(All the Rates are for “All Ages” Relate to 100 Workmen; the Others to 100 Workmen from 25-34 Years of Age)

<table>
<thead>
<tr>
<th>Age group</th>
<th>Causes of sickness</th>
<th>Days of sickness</th>
<th>Infectious</th>
<th>Poisonous</th>
<th>Nervous diseases</th>
<th>Respiratory diseases</th>
<th>Circulatory diseases</th>
<th>Disease of the skin</th>
<th>Muscular and articul. rheumatism</th>
<th>Digestive diseases</th>
<th>Foul</th>
<th>Accidents</th>
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<td>530</td>
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<td>—</td>
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Kober and Hayhurst give the following mortality figures by age groups among 131,264 American masons employed in 1920:

<table>
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<th>Years of age</th>
<th>From all causes (absolute figures)</th>
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</table>

Ascher reports (1905) that, among 5,685 masons who were members of the Sickness Society of the Berlin Masons, 2,181, or 38.2 per cent., had recourse to sick pay on account of sickness or accident which could be classed as follows: external lesions, 18.3 (more than half of which, 55, were accidents from work); respiratory diseases, 20.7; rheumatism, 7.6; diseases of the blood, 2.6; diseases of the digestive tract, 7.6; nervous diseases, 5.08; diseases of the genito-urinary tract, 0.9; diseases of the skin, 57; acute infectious diseases, 6.

The old statistics of Hirt showed that of 1,038 masons 34 per cent., suffered from pulmonary diseases, of which 12.9 per cent. were tuberculous.

In another set of statistics Kober and Hayhurst give the following percentages of the different causes in 2,399 deaths of stonemasons and bricklayers:

- Tuberculosis, 13.9;
- Pneumonia, 8.2;
- Other respiratory diseases, 2.5;
- Diseases of the heart, 13.2;
- Diseases of the digestive tract, 2.3.

Hoffmann’s statistics relating to 1,467 deaths from all causes show a mortality rate of 31.1 per cent. for diseases of the respiratory tract, that of tuberculosis being 17.7 per cent. The death rate from diseases of the urinary tract is 13 per cent. and from heart disease, 10.1. Gher-
ardi published, in 1921, the results of a study, covering a period of twenty years, 1897-1916, relating to 111,920 deaths among masons, that is, an average of 5,596 annually, which gives a mortality rate for masons of 16.1 per 1,000 as against 21.1 for all professions (including infantile mortality) or 16.7 per 1,000 for males in all professions above fifteen years of age. It is seen that mortality from all causes is less than the general average and, according to this authority, it is the same also for acute diseases of the respiratory tract. He does not give figures of deaths from specific causes.

Hoffman gives a mortality rate for accidents of 9 per cent., that for journeymen being 3.8 and for apprentices 6. For the period 1897-1916 Gherardi shows for Italian masons the following mortality rate per 100,000:

<table>
<thead>
<tr>
<th>Accidents</th>
<th>Falls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males over 15 years ..........</td>
<td>42.8</td>
</tr>
<tr>
<td>Masons ..................</td>
<td>39.3</td>
</tr>
</tbody>
</table>

While deaths from falls constitute 38.4 per cent. of cases of death from accidents of all kinds for males above fifteen years, this figure for masons rises to 56, that is, nearly a half more.

Deaths from falls, however, increased in the second decennial period under review (1907-1916), because at Milan for the period 1896-1906 (eleven years) they numbered 59 deaths, that is, 5.4 per year, and for the period 1907-1912 (six years) there were 92 deaths or 9 per year.

The number of accidents from falls is still higher if the non-fatal cases be included.

Cases of poisoning by carbon monoxide have been reported in various German inspectors' reports (1900, 1908, 1913) as occurring among watchmen. Among paper-hangers Hoffmann has shown that of 319 deaths in this class 107 or 33.5 per cent. were due to tuberculosis, 11.1 to other lung diseases, which gives a total of 44.6 per cent, for diseases of the respiratory tract. The normal percentage to be expected should be 23.6 per cent.

**PATHOLOGY**

Exposure to inclement weather conditions brings on maladies due to cold; neuralgias, chronic articular and muscular rheumatism, lumbago, sciatica, etc., especially in old workers. Occurrence of respiratory diseases, bronchial catarrh, asthma, tuberculosis, is further favoured by the local action of dusts.

The dangers from heat stroke are much less frequent.

The continuous standing favours the development of varicose veins, phlebitis, etc. According to Descamp, tilers and slaters show, as a result of work done in the open air at a certain height and in a bent position on slippery surfaces, a certain numbness of the legs accom-

panied by loss of sensitiveness and muscular tremor. In young workers these symptoms disappear when they get to the ground, but in older workmen a kind of paralytic weakness affects the lower limbs and renders them incapable of climbing. According to information from the local sickness societies of Berlin, these workmen have to give up between forty-five and fifty years of age.

The position assumed may involve other lesions: synovitis, inflamed bursae, etc.

Lifting and carrying weights that are too heavy causes especially acute hernias due to strain. It does not appear, however, that these are more frequent among the masons than among others. It is not so though with the labourers, which is due to the fact that they have generally a less sound constitution. Mention should be made also of the development of bruises and ulcers on the shoulder, callosities, formation of rhabades, and, as the result of always carrying loads on one side, changes in the shoulder blade, the upper part of the neck and the thorax.

Working the stone, use of cement and lime, and the dust produced cause various kinds of lesions. Of these, dermatitis ranks first (cement workers' itch). While the predisposing causes are mainly of a physical nature (humidity, maceration of the horny layer, dusts, various traumatic agencies favouring abrasions and excoriations), the determining causes are essentially due to the alkaline earthy bases of the lime, the sulphuric acid, and the alumina in the cement. The lesions are situated on the hands, the interdigital spaces, the wrist, and, more rarely, the palm; the lesions sometimes may extend to the forearm and chest. They may start with isolated or confluent red plaques, showing an infiltration of the derma and papillary layer with oedematous itchy swelling. In the second stage small isolated vesicles, sometimes confluent, develop, changing into dry pustules, grey or yellow, and later followed by desquamation. The nails show transverse fissures owing to the detachment of the superficial layer from the bed. As complications lichenisation and purulent dermatitis have been found. This condition lasts for a long time, treatment is rather difficult — the more so as the disease proceeds by successive attacks (Artom).

Without giving figures, Martial (1906-1908) states with confidence that a third at least of the persons handling line and cement show cutaneous lesions, and Besnier (1907) insists on the
fact that dermatitis is much more widespread than is believed, as only a small proportion of those affected for medical treatment, the doctor rarely being called on to treat the lesions.

Conjunctivitis is observed as a result of particles of cement, lime, stone, iron, or wood getting into the eyes. The pulmonary troubles found are due to the dust setting up pneumoconiosis among dressers and polishers of stone. These anatomical changes are characterised by a chronic interstitial irritation, which leads to the formation of fibrous tissue, the lung being sown with numerous nodules the nature of which depends on the kind of dust involved. This is the reason why those who work with the chisel on fine sandstone are more predisposed to tuberculosis than those who work on granite, of which the dust is heavier.

It is not necessary to describe in more detail the morbid symptoms set up by the poisons.

In the development of the different morbid troubles account must be taken of individual predisposition. This explains why the morbidity and mortality among masons, despite the risks, does not reach the general average. Only strong young men take up the work, entering the trade young and developing and strengthening their physique (Gherardi). It is remarkable how different the conditions are in the case of the labourers, who are nevertheless subjected to the same influences. Teleky explains this by the seasonal nature and uncertainty of the work adopted by persons without professional instruction, of poor constitution, and low social level, who have not been able to find employment in other trades.

A factor aggravating the pathological findings may arise from the abuse of alcohol and tobacco. It is a regrettable fact that the number addicted to alcohol among the labourers is double or treble that of the average. Interesting research has been effected in relation to masons’ work, on the lines of scientific management with motion study; it will suffice to cite the classic work by Gilbreth and the recent studies (1927) of G. Lehmann and Baader, etc.

**HYGIENE**

Preventive measures are essentially of a general nature.

As means of protection against bad weather conditions, installation of wooden sheds, capable of being heated when necessary, is recommended. They can be used by the workmen for taking their meals, changing their clothes, and washing.

Protection against damage caused in carrying heavy loads can be best obtained, on the one hand, by using as far as possible mechanical means of lifting and carrying and, on the other, by placing a limitation on the weight to be carried by the workmen. The neck and shoulders should be protected by a cloth.

Damage from dust can be partly avoided by moist methods of working (sawing and polishing stone) or in working on the lee side of the wind. Further, wider and wider use of automatic apparatus for making cement and mortar will much reduce the risk caused by the dust of these substances.

Scraping down old painted wallpapers should also be carried out by wet methods and the usual precautions adopted in regard to the danger of poisoning by lead, arsenic, chrome compounds, etc.

To guard against poisoning from carbon monoxide the use of open braziers for drying new houses should be prohibited, or allowed only under certain conditions.

Means for cleanliness (wash basins, soap, etc.), medical supervision of the personnel, instruction of the workers as to the professional risks and dangers run (by issue of leaflets and warning notices), as is done by certain German associations, are specially suitable measures. All measures of safety against accidents (on scaffolds, etc.), must be taken.

**LEGISLATION**

In Czechoslovakia an Act was passed on 7 April 1927.

**France:** Limitation of the weight of the loads (Decree of 29 December 1909). A Decree of 9 August 1925, amended 10 March 1927, lays down the measures of health and safety for persons employed in building yards.

**Germany:** Employment of women is prohibited (Police Orders in various States); the use of open braziers is prohibited (Orders of 4 July and 10 December 1913); sanitary supervision of the yards by factory inspectors is demanded. Section 120 of the Labour Code contains regulations in regard to building sheds and yards. In 1925 a draft Order was issued for the protection of persons employed in building construction covering the following points: prevention of accidents, welfare, drinking water, first aid, etc.

**Great Britain:** The Building Regulations dated 21 June 1926 are in force.
In the Irish Free State an Order affecting the building trade was issued on 10 November 1926.

The Act of 18 August 1924 and the Grand Ducal Decree of the same date deal with measures of health and safety for persons employed in building in Luxembourg.

Notification of the following conditions and diseases is obligatory in the Netherlands: synovitis and bursitis of the knee in masons and slaters, diseases of the skin, dermatitis and eczema, inflammation of the joints, tendons and subcutaneous cellular tissue, ulcers of the cornea and conjunctiva.

On the subject of compensation for dermatitis, see article "Skin Diseases".

Compensation for miners' phthisis in South Africa was extended so as to cover masons working outside the mines in 1926.

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Buttons (Manufacture of)


RAW MATERIALS

Buttons began to be generally employed as fastenings as early as the 15th century. They are made of metals (brass, iron, gold, and silver), jewels, filagree, ivory, horn, bone, mother of pearl and other nacreous products of shell fish, vegetable ivory, wood, glass, porcelain, paper, celluloid, and many other artificial compositions. Ivory buttons are amongst the oldest of all. Glass and porcelain buttons are chiefly made in Bohemia. Buttons of vegetable ivory, which now form one of the most important branches of the American button industry, were first made in 1859. The freshwater pearl button industry has developed greatly towards the end of the 19th century, especially in the region of the Mississippi, and these buttons, together with ocean pearl buttons, represent over 50 per cent. of all the buttons manufactured in the United States.

TECHNOLOGY

Buttons were first fashioned separately by skilled artisans, but later, to reduce the cost of production, they were stamped out in dies instead of being cut, engraved and ornamented by hand.

Vegetable ivory or African ivory or corozo nuts are the names given to the seed of the fruit of the ivory palm (Phytelephas macrocarpa) often known as the ivory nut. It resembles genuine ivory in texture and colour, and is about the size of a hen's egg. These nuts are first cleaned by being made to revolve in a cylindrical drum, which permits the dust and shells to drop down. This drum revolves in a closed envelope and is emptied from time to time. The shells are used as combustibles and the nuts pass to a circular saw, subsequently to lathes, and later to another revolving drum for pouncing. They are then polished with sawdust, and bleached with hydrogen peroxide. The dust and waste are sometimes utilised as manure. When used for making beads, the material is first dampened. Beads and buttons are cut out on lathes and often engine-turned.

For the manufacture of buttons, studs and ornaments from freshwater pearls, the shells of molluscs are used. These are cooked and freed from fleshy parts, sorted into sizes and soaked for several days to render them less brittle. While still wet they are sawn into blanks and subsequently cut into discs, bored, planed, faced, ground, polished, and domed.

Bones coming from America are very often boiled, prior to export, but nevertheless they still exhale a very characteristic odour. The work on these involves: cutting into strips of required thickness by means of circular saws, work on a lathe (cutting out), boring, polishing in a drum, sorting, arranging in sizes, and packing.

STATISTICS

Button makers are one of the occupational groups included in a study of workers exposed to different kinds of dust carried out by the Prudential Insurance Company of America amongst workers exposed to general organic dust.

Mortality statistics of button makers in the United States, based on 127 deaths from all causes, show 48 or 37.8 per cent. to have died from consumption as compared with 14.8 per cent. for males in the registration area, while there were in addition 14 deaths, or 11 per cent., from other diseases of the lungs. Of 390 deaths among button workers in Vienna, 1895-1905, 272, or 69.7 per cent., were due to tuberculosis, and an examination of 150 pearl button workers conducted by Teleky in 1907 revealed 93 only to have normal lungs. (See also article "Mother of Pearl").

SOURCES OF DANGER

Mortality statistics for respiratory diseases would appear to indicate that the trade under consideration involves a serious health hazard, but it must
be remembered that the very considerable labour turnover plays an important role in this industry. Inspection of a sawing department (pearl buttons) revealed the belts, machines, walls, ceiling, clothing, and even faces of the workers to be covered with fine white pearl dust, even with the existence of suction devices for dust removal.

An extremely fine dust (finer than that produced in sawing) is produced by the machines used for cutting out the buttons, and drilling holes in them, and also during the polishing; but here exhaust hoods effectively installed afford adequate protection. Engine-turning of vegetable ivory (beads) is done on lathes and gives rise to fine dust, which calls for the installation of a good exhaust hood. The inhalation of the fine dust thus produced predisposes to diseases of the respiratory organs. Ivory dust, like horn dust, is composed of sharp, angular particles, and therefore very harmful.

Amongst female workers and minors engaged on the production of pearl buttons, dyspeptic and catarrhal affections of the respiratory passages, with subsequent more serious developments, have been noticed and ascribed to dust inhalation. Further, vegetable ivory lending itself particularly well to application of colour, its manipulation offers additional risk from the use of toxic colouring matters, where these are used.

In 1907, De Marbaix noted amongst the workers engaged in a bone-button factory in Antwerp that a special disease ("bone-button makers' disease") affected all the workers without exception. All workers inevitably contracted one attack of this disease which appeared to confer certain immunity, and which consisted in benign inflammation [infection?] of the fingers, healing subsequent to invariable suppuration. The workers, especially those engaged on machine work, continually suffer from cuts, scratches and superficial sores on the fingers, caused either by the machine or, more frequently, by the numerous ragged fragments and fine edges of the bone. The workers have, besides, their hands and, in fact, their whole bodies powdered over with an impalpable bone dust, which constantly floats in the atmosphere of the factory. At a given moment one of the scratches in question becomes infected, giving rise to the affection known as "bone-button makers' disease".

The workers in question also run the risk of exposure to infectious diseases (especially anthrax) in the event of the raw material coming from an infected animal.

The work of scouring metal buttons involves exposure to the risks attending this operation.

Finally, an important factor in fatigue is provided by the following circumstances: in the last few years the manufacture of buttons has come to be almost entirely automatic. Nevertheless, workers skilled in rapid work are still required for making certain buttons (especially mother of pearl). It is here of interest to recall Frois' remarks regarding the movements of a woman worker engaged in making buttons on a small lathe. This worker made approximately 1,776 buttons per hour, or one button every two seconds.

The worker in question attained this speed by effecting a series of very rapid movements: one of the right foot from right to left, to bring forward the small wheel for smoothing the face of the button, and simultaneously a movement of the right hand for placing the button on the chuck; another of the left hand for bringing forward on the chuck a ring to hold the button in position. These three movements have a certain range and demand perfect dexterity. In one hour the worker effects 1,776 movements of the right foot and in the same time 1,776 movements of the right hand, and 1,776 movements of the left hand — totalling three simultaneous movements every two seconds. Reckoning also the return movements, this means that the worker effects three simple movements every second.

**HYGIENE**

The aspiration and removal of dust should be specially aimed at in this industry. It would be possible in certain instances to substitute wet processes for dry.

Some practical difficulties are encountered in connection with dust elimination as regards sawing operations, in course of which the workers are exposed to large quantities of sawdust which are with difficulty removed by suction, since with the best protective devices some dust escapes. It is advisable to disinfect bones especially those coming from countries where anthrax infection is rife, and where disinfection has not been effected prior to export.

Adequate precautions should be adopted during scouring of metal buttons.

The makers of metallic buttons use presses, punches and other tools which
stamp out the metal by blows or by successive pressure.

The bad effects of this work are chiefly connected with noise and shock. It is therefore advisable to set up such presses and punches on foundations free from the walls of the workroom, to limit the number of such apparatus, and to provide them with wooden or rubber shock absorbers or insulating devices calculated to deaden the shock.

The work should be so organised as to prevent undue fatigue of the women workers occupied at lathes. The working day should be so arranged that the very rapidly repeated movements demanded by the machine work may not give rise to chronic fatigue and overstrain.

LEGISLATION

Amongst the countries which have drawn up provisions offering protection to workers employed in the button industry may be mentioned the following:

Belgium: exclusion of young persons under 14 years of age from the manufacture of metal buttons (scouring departments).

France: exclusion of young persons under 18 years of age from work on machines for making of metal buttons as well as presses and punches with automatic working, when dust is disseminated freely throughout the workshop.

Italy: exclusion of boys under 15 years of age and girls under 21 from sorting of bone and horn for the manufacture of buttons, etc.

Spain: exclusion of boys under 16 and girls under 21 from the manufacture of buttons; etc.

Certain legislative provisions provide for the exclusion of young persons from the work in question by the inclusive formula: "from all operations involving dust production".

Prof. G. M. Kober
(Washington).
Cadmium

French: Cadmium. — German: Kadmium. — Italian and Spanish: Cadmio.

Cadmium (symbol Cd, atomic weight 112.4) is a white malleable and ductile metal with a density of 8.65. It melts at 320° C. and boils at 778° C.

Cadmium when heated in the presence of air burns and gives a yellowish-brown oxide. It dissolves with liberation of hydrogen in sulphuric hydrochloric and acetic acids, forming the corresponding salts. Salts of cadmium when dissolved give a yellow precipitate of sulphur of cadmium with hydrogen sulphur and the alkaline sulphurs.

Cadmium is found in the soil in the state of sulphur (greenockite); it is present with zinc in zinc ores (Silesia, Freiburg, Derbyshire, Cumberland), the ores in question containing also lead, iron, and sometimes arsenic.

**INDUSTRIAL OPERATIONS**

Cadmium distils first when zinc ores (see article "Zinc") are treated, and becomes condensed in the extensions of the retorts. The first dust (cadmia) deposited in these extensions is collected and dissolved in sulphuric acid. A current of sulphuretted hydrogen then precipitates the cadmium in the form of sulphur, but the precipitate contains a little copper and zinc; in order to eliminate this, the sulphur is dissolved in hydrochloric acid and treated with ammonium carbonate. It can also be got from ashes of zinc.

Metallic cadmium serves in the preparation of welding materials with a low melting point and in the manufacture of different derivatives, particularly sulphur derivatives. It is found in certain kind of brass.

Cadmium sulphur or cadmium yellow (CdS) is used in the painting industry for its beautiful colour. It has a high covering power and resists light and damp very well.

A solution of cadmium nitrate is prepared by dissolving in nitric acid cadmium quite free from lead. The solution is precipitated by carbonate of soda; then the carbonate of cadmium thus obtained is transformed into sulphur by means of a solution of sodium sulphide. For the latter operation there is also used, but less frequently, a current of sulphuretted hydrogen.

Different colours are obtained; straw, lemon, orange, red, etc., according to the temperature at which the precipitations and the concentration of the reagents are effected.

Cadmium yellow cannot be mixed with colours with a lead basis, for formation of lead sulphide produces blackening. Its high cost prevents it being used except in art painting.

**Cadmium iodide** is used in medicine and in photography. It is prepared by digesting iodine and cadmium with water.

Austria, Germany, and the United States occupy the first place as regards the production of cadmium:

<table>
<thead>
<tr>
<th>Country</th>
<th>Production (lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>275,520 in 1923</td>
</tr>
<tr>
<td>U.S.A.</td>
<td>249,923 in 1922</td>
</tr>
<tr>
<td>Germany</td>
<td>296,000 in 1918</td>
</tr>
</tbody>
</table>

**PATHOLOGY**

Marme quoted by Tracuski (Silesia) has already drawn attention to the fact that cadmium causes the following disorders: gastro-enteritis, emaciation, fatty degeneration of the heart and the kidneys.

Erben and Kober hold that the action of the salts of cadmium is analogous to that of zinc salts. Cadmium was considered by Sigel to be the cause of brassfounders' ague, but this theory has been abandoned, as likewise that of Gadamer, which attributed to cadmium the forms of irritation of zincfounders. The data provided by this author, as well as by Erben, were based on a report by Tracuski, according to which fumes from zinc factories were said to contain 3 per cent. of cadmium. In fact they contain up to 5 per cent.
According to Schwarz and Otto the sulphate, the carbonate, and the oxide of cadmium are said to give rise to the following symptoms among animals: marked emaciation sometimes followed by death, modification of the blood picture, diminution of the haemoglobin, of the number of red cells, of the polymorphonuclears, increase of the lymphocytes. Irritation of the conjunctivitis and the mucus of the respiratory passages has been noted.

An interesting case of poisoning by cadmium was reported in 1914, in Saxony, in a factory where cadmium plates for electric mines were made. One of the workers engaged at the press complained of weakness, lack of appetite, and nausea. This condition lasted for three weeks and was attributed to the presence of salts of cadmium oxide in the stomach, absorbed by dust inhalation or by absorbing with food. Dust samples were sent to Dresden for analysis. The analysis proved that the dust was not solely constituted of metallic cadmium, but also of traces of cadmium oxide and insoluble cadmium salts; but present to such a feeble extent, however, that they could not injure the worker's health.

Stephens (1920-1921) found cadmium in the liver of an old Welsh workman whose case had been diagnosed as lead poisoning, though the characteristic colic, peculiar to the latter poisoning, was lacking. The liver contained in fact 0.120 grm. of cadmium per kilo, and 0.05 grm. of zinc. The presence of lead was not discovered.

In Germany there were recently reported cases sometimes fatal in the course of the production of cadmium; these cases were due to arseniuretted hydrogen (Fischer).

A fatal case of poisoning by cadmium fumes was reported (Legge) in Great Britain in 1928. It affected an engineer in a colour factory, who had been in the habit of receiving the metallic cadmium in sticks the length of a pencil. A few months before the accident the cadmium arrived in ingots, which had to be melted in a crucible, heated by gas and not connected up to a ventilation pipe. Two workmen assisting him became seriously ill also, but recovered later. The symptoms complained of were the following: dryness of the throat, headache, rapid pulse, nausea, brown colour of the urine, shivering.

The autopsy showed signs of congestion of the larynx, the trachea and the bronchial tubes and acute inflammation of the stomach and intestines, fatty degeneration of the heart and liver, haemorrhagic inflammation of the spleen, and inflammation of the kidneys.

Kochmann recently (1925) studied the pharmacodynamic action of cadmium. which, according to his research, would appear to possess properties analogous to those of zinc and mercury; it is principally astringent, caustic in high concentration and inductive of hyperaemia.

Otto has continued his experimental research on cadmium oxide at the stage of production making cats inhale air containing 2 mg. of cadmium fumes per litre for from 2½ to 15 minutes and during 10-16 days.

The experiments have proved that the fumes of cadmium oxide when inhaled cause fatal pneumonia or broncho-pneumonia due to the local irritant action of cadmium. The latter resembles zinc very much, but while zinc fumes are, particularly in the brassfoundries or in the course of autogenous welding, notoriously the cause of brassfounders' ague, they do not exercise any serious local action. It is therefore to be recommended that health authorities should require effective local exhaust ventilation in all cases in which the liberation of cadmium fumes is to be feared. The question of whether certain respiratory troubles (catarrh, pains in the chest) met with amongst zincfounders should be attributed to cadmium is one which calls for further detailed study.

HYGIENE

Although cadmium only plays a secondary role in industry, the fumes and dust of this product ought to be removed wherever they occur as in all metal foundries.

BIBLIOGRAPHY


**Calcium**

French and German: *Calcium*. — Italian and Spanish: *Calcio*.

This metal (Ca) is very widely distributed in the state of carbonate (limestone, marble), sulphate (gypsum), fluoride, silicate, phosphate, etc.

It is slightly yellowish in colour, ductile and malleable, and oxidises easily on exposure to damp air. It is prepared by electrolysis from chloride of molten calcium. The chloride is decomposed in a carbon vat which serves as the anode; the cathode is represented by steel wires placed vertically along the axis of the vat, and it is to these wires which the metal droplets adhere firmly. By raising the cathode slowly there is obtained, by means of successive deposits, a large stick of calcium.

During the war, calcium hydride, or hydroth, was prepared and used in the manufacture of hydrogen for aircraft. In the metallurgical industry it serves for dioxidising and fixing nitrogen. It is used in the manufacture of certain alloys, etc.

Amongst these compounds the most important is oxide of caustic lime (see article "Lime"). Less important from a practical point of view is slaked lime (Ca(OH)) which, however, exerts a caustic action on the mucus membrane (especially the conjunctiva).Arsenate of calcium is at present widely used in the campaign against vegetable parasites. The chloride exerts a narcotic action on the mucous membranes. Nitrate is used in the manufacture of calcium cyanamid and artificial manures in general (see article "Fertilisers").

Another compound, calcium carbide, is produced by one of the oldest electrochemical processes, dating from 1894 (see article “Calcium Carbide”).

Calcium is not of itself of any importance industrially. On the other hand, its compounds are of importance (basic slag, see that article).

Three cases, one of which was fatal, due to sulphuretted hydrogen have been reported in a German tannery where a vat had been filled by lactic acid instead of sulphuretted compound of calcium.

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**Calcium Carbide**


**TECHNICAL DATA**

Calcium carbide, a solid dark-grey substance, is prepared by heating in an electric furnace a mixture of lime and of coal (CaO-3C = CaC2-CO). Anthracite of good quality or coke from a gas or metallurgical factory is used. The lime must be very pure (97% of CaO) and the constituents must not possess more than a very slight phosphorus content.

The raw materials are, on their arrival at the factory, stored in silos. Before mixing they are submitted to mechanical crushing. Sixty parts of lime and forty of coal are mixed with the shovel or mechanically; for instance, by allowing the coke and lime to pour into a large pipe on issuing from the measuring hopper, a slight vacuum being maintained. Separation of dust is often effected by mechanical devices.

The furnaces are charged either by shovelling after the mixture has been placed on the charging hearth or by skips, or through chutes leading directly into the furnaces. The latter are always situated in large shops, very high and well-ventilated, for they give rise to great heat and liberate much carbon monoxide. Electric arc furnaces using alternating single, two and three phase current are in principle composed of a sheet-metal interior, lined with refractory material composed chiefly of magnesia. The lower electrodes of graphite are embedded in a cast-iron hearth and are level with the surface of the lining covering the bottom of the interior of the furnace. The upper electrodes, likewise of graphite, dip down into the interior of the furnace, being maintained there by a system of suspension, which allows of their height being regulated.

While the pressure on the furnaces varies between 75 and 95 volts, the current strength is on the contrary enormous — 30,000 to 80,000 amperes, and even over that — this explaining the great heat given off. Since the pressure must remain constant, and there is interfered with by the wearing down of the electrodes, it is necessary to provide for adjustment every minute. Every pair of furnaces must, therefore, be supervised by a workman, who, as soon as pressure falls, sets in motion a small motor to lower the electrodes. The worker in question works in the
Transformer shop and is not exposed to dust, but his task is exhausting on account of the high degree of attention demanded. Many factories have now installed an automatic adjustment device for the furnaces.

The majority of furnaces are open, but certain types (the Norwegian, for instance) are closed and provided with exhaust ducts for the carbon monoxide.

Production is continuous; the mixture of the lime and the coal is constantly fed into the furnace from the top, and periodically (eighteen times in the twenty-four hours on an average) the carbide is tapped issuing from the tap hole situated in the lower part of the furnace. At other times this hole is obstructed by solidified carbide. When tapping takes place, the worker approaches the hole with an iron bar led to earth by large conductors. A sparking discharge is set up between the iron bar and the furnace, and the plug of carbide is reduced to a liquid state in a few minutes.

The liquid carbide flows into a cast-iron mould as soon as hardening takes place, is cast in a shell and separated from the mould. Later, the shell is broken, and the carbide can be broken up with a pickaxe into large pieces, which are transported to crushing machines, generally of the revolving cone type.

The pieces of carbide are no longer done by hand, but by using two kinds of apparatus: the drum (a sheet-metal cylinder revolving round an inclined axis having holes of increasing diameter) or a kind of shock transporter with an apron, perforated in the same manner. Cast-iron ducts receive the pieces of carbide and convey them to metallic barrels, which are hermetically soldered as soon as filling is effected.

These operations raise great quantities of dust which should be removed by suction and cast outside.

Carbide of calcium is found on the market in three forms: unprepared, crushed and sorted, and granulated.

This product has only two industrial uses, but these are very important: preparation of acetylene (see that article) and manufacture of calcium cyanamide (see also that article). The market value of carbide depends on the volume of acetylene liberated per kilogram of the product in presence of water. Ordinary carbide is generally "at 300 litres". The volume of acetylene given off is carefully checked in the laboratories of carbide factories, as well as the phosphorus content, which must be very low to prevent formation in presence of water of phosphoretted hydrogen, which is poisonous and liable to spontaneous ignition.

Sources of Danger

Danger is mainly connected with impurities contained in this product: phosphoretted hydrogen (which according to Jokote is present in acetylene obtained from American carbide in a proportion of 0.04 per cent., and according to Lunge and Cedernkreutz may attain the value of 0.06 per cent.), ammonia, sulphuretted hydrogen, acetylene (in presence of moist air), silicon carbide, ferrosilicon, sulphur, and calcium phosphorus. During production, the workers attending the furnaces are exposed to the risk of carbon monoxide poisoning.

Apart from injury to the mucous membrane by the carbide (caustic) and to the skin (as a result of prolonged contact: skin eruptions, eczema, ulcerations), experts on the subject assert that the carbide industry when effected under good conditions is not now more dangerous than other industries.

Attention must, however, be drawn to the risk of explosion when soldered receptacles are opened, as these often contain acetylene under pressure which ignites at 480° C. The soldering medium melts at 180-230° C., however. It is therefore necessary to guard against using unduly hot tools or a naked flame. Egli and Rust quote the case of a worker whose face was burnt by an acetylene flame during soldering of a tin box containing carbide.

Pathology

Occupational dermatitis due to carbide was reported for the first time in 1913 by O. Sachs, of Vienna, affecting a worker in a carbide factory for the preparation of acetylene gas.

Carbide causes two kinds of skin lesions: dermatitis due chiefly to handling of hard and dry carbide and then lesions in the form of necrotic ulcers with clearly marked edges. When the hands come in contact with the liquid a well-known reaction follows, causing ulceration of the skin, analogous to that caused by caustic lime. The lesions are chiefly situated on the pads of the fingers, where there are frequently found scars of lesions already healed. The use of leather gloves is not advisable, for the carbide attacks them very rapidly and comes in contact with the skin.

Hygiene

Besides general measures of hygiene, it is advisable to install the tap hole, which gives off great heat, below the
level of the flooring of the workroom. Certainly the special conditions in this industry do not permit of the work being effected in perfectly healthy surroundings, yet individual precautions can effect remarkable improvement: prevention of the escape of dust and gas. The workers should wear smoked glasses. Adequate protection of the mouth and nose should be provided (a handkerchief damped with pure water, since the workers are averse to wearing masks). Good sanitary installation to permit of personal hygiene is necessary.

Workers engaged in handling carbide should protect their hands by application of perfectly anhydros pure American vaseline, which is applied to the hands before putting on gloves made of sailcloth. Leather gloves should be absolutely forbidden. Receptacles containing carbide should be stored in dry, well-ventilated places. Precautions against fire should be adopted.

**LEGISLATION**

See article "Acetylene".

In Switzerland injury caused by calcium carbide is compensated in the same manner as accidents.

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**Calcium Cyanamide**

French: Cyanamide de calcium. — German: Kalkstechstoff or Kalziumcyanamid. — Italian: Calciocianamida. — Spanish: Calcio cyanamida.

**CHEMISTRY**

The commercial product known under the name of nitrolime is a lustrous greyish-black powder with an oily feeling to the touch — not dusty — partially soluble in water, which contains about 57 per cent. of calcium cyanamide (CN Na or Ca CN.) 21 per cent. of quicklimes, 14.18 per cent. of carbon; about 10 per cent. of various impurities of little importance, derived from chlorine (up to 6 per cent. of calcium chloride, added at the time of its manufacture), iron, salicylic and phosphoric acids, acetylene, phosphuretted hydrogen, and sulphuretted hydrogen, etc. The total content in nitrogen is from 17-20-24 per cent., in calcium from 40-42 per cent., corresponding to 56-57 per cent. of calcium oxide.

In a moist atmosphere the nitrolime gives off small quantities of ammonia; acted on by hot water it gives rise to dicyanamide (C, N4 H4) and other products. Under the action of steam under pressure all the nitrogen in the lime is converted into ammonia, and it is on this reaction that the industrial process for the manufacture of ammonia and its salts is based. Calcium cyanamide is a valuable manure, which in the soil is decomposed into ammonia and nitrates under the action of warmth, humidity, and the acids of the humus and bacteria.

**PRODUCTION**

When a current of nitrogen is made to pass over calcium carbide at high temperature the salt calcium cyanamide is formed. Industrially, carbide of calcium in powder form is introduced into a vertical furnace built of refractory materials and provided with a cover. The broken-up carbide is placed in a retort in the middle of an electric furnace and transformed, by means of heat generated by the resistance, under a current of pure dry nitrogen obtained by the rectification of the liquid air through pipes arranged in the lower part of the apparatus. The nitrogen can also be obtained by making the air pass over copper at red heat. The reaction being exothermic, it is sufficient to begin by heating to 700-1000° C. for some time. The cyanamide is dissociated above 1360° C. It comes out of the electric furnace in the form of a compact black mass which then requires to be crushed and pulverised in ball mills. Hydration follows with water (5-9 per cent.); it is then granulated or oiled (2-4 per cent. of heavy mineral oil) and bagged or packed in cans of corrugated sheet metal.

When the crude cyanamide is to be used as a manure, the operation of finishing is practised with the object of decomposing any traces of carbide remaining in it and converting it into an oily powder easy to handle. The dicyanamide (C, N4 H4) has the form of colourless inodorous crystals, almost insoluble in cold water, soluble in boiling water; melting point 16° C. It is employed in the manufacture of explosives, of colouring agents, cyanures, urea, salts of hydrazone, etc.

The cyanamide is used as a manure, for the manufacture of cyanures, urea, guanidine, etc., and as a constituent of the powder applied in the tempering of metals.

**TOXICITY**

Accidents from calcium cyanamide do not occur, except when the product is in the form of dust, whether in the course of manufacture, packing,
transport, or in its use in agriculture. Its effect is exerted at first on the skin and exposed mucous membranes. The fine dust can, however, like all fine dust, reach the respiratory tract, but only a small portion reaches the deeper recesses, as most of it gets deposited on the mucous membrane of the nose and large bronchi, whence it is coughed up. A very small quantity is swallowed and reaches the intestinal tract.

The action of cyanamide is due mainly to the action of two of its constituents, lime and cyanamide. The lime irritates the tissues, in consequence of a dehydrating action and power of coagulating the albuminous substances. The lime irritates the tissues, in consequence of a dehydrating action and power of coagulating the albuminous substances with concomitant heat production. The epidermis is raised and softened, and this process, favoured by a preliminary or concurrent moistening of the skin by humidity (rain, mist, sweat, mucous secretions), is rather severe when the epidermis has disappeared or in the presence of small wounds, cuts, and scratches. This action is, perhaps, due to ammonia liberated on the decomposition of the nitrolime by heat. When nitrolime is inhaled as dust, inflammation of the bronchi and bronchioles results.

The researches of Gergens and Baumann, Lange, Coester, Stritt, Koelsch, Hesse, and others have elucidated the toxicity of cyanamide by subcutaneous injections of doses of from 5 to 10 mg. per kilogram weight in the frog, of 0.1 to 0.3 grm. per kilogram weight in the rabbit. Respiratory distress accompanied by secondary cramps, salivation and diarrhoea ensue, which they consider to be specific. The fatal subcutaneous dose is 20 mg. per 50 grm. weight of the frog, and from 0.5 grm. per kilogram weight for the rabbit; a dose of 0.75 to 1 grm. when swallowed is fatal for the rabbit. In carnivora this dose is 5 or 6 times smaller. Chronic poisoning has never been observed. Accumulation does not seem to be produced.

Cyanamide, when it has been absorbed by man in the form of nitrolime, either by the respiratory or digestive tract, becomes converted into carbonate of calcium or reconverted into cyanamide (CN.NH₂), under the influence of the moisture, heat and carbonic acid gas present. It seems to act directly upon the respiratory centres—a phenomenon which has also been observed in animals (Koelsch).

In very marked cases the blood shows, on spectroscopic examination, a dark line in the yellow-green portion, as well as an appreciable darkening towards the extremity of the spectrum in the green blue, modifications recalling the spectrum of cyanmethaemoglobin (of cyanhaematin). Fatal poisoning is unknown— the minimal dose being too great ever to be reached in ordinary practice. It must certainly be from 40 to 50 grm. of nitrolime for an adult.

Langlois found (in 1912) during an enquiry in a cyanamide factory, where the workmen refused to continue working, that wine played a role in the genesis of the trouble. This fact was subsequently confirmed by Italian and German enquiries. Koelsch considers that alcohol renders the system susceptible to the action of cyanamide—an action similar to that which it exerts in respect of nitro and amido derivatives of benzene; or again of light on eosin, haematoporphyrin and similar fluorescent substances. On the other hand, Hesse is of opinion that cyanamide is capable of giving a potential action to a series of physiodynamic substances—both paralysing and exciting—due probably to the increase in the receptivity of the nervous system for certain substances (solubility of cyanamide in liquids). Alcohol, chloral, chloroform, vohimbine, codeine, papaverine, atropine, etc., have the same property.

More alcohol has been found in the brain of animals that have been treated with cyanamide previously than in the controls.

There is no doubt that the action of cyanamide-alcohol, which recalls that of nitrite of amyl, differs in several respects from ordinary alcoholic intoxication. Further, there are other specific central effects of cyanamide. The relative fugitiveness of the symptoms is due to the fact that cyanamide is rapidly decomposed, and that the quantity of dust which is absorbed into the system is minimal. The researches of Raida, however, have proved that cyanamide is distributed indiscriminately throughout the organs without preference for any special one, and that decomposition is already in progress during the first hour following absorption. 70 per cent. of the cyanamide is then changed into urea and excreted in the urine. The ingestion of alcohol effected simultaneously, though giving rise to typical combined action has no influence on the disappearance of cyanamide from the circulation and tissues.

Lo Monaco, who carried on the researches begun by Hesse, arrived at the conclusion that the action of cyanamide alcohol was the same in animals as in man, and attributed
the toxic action to the group CN, augmented by the group NH₂, while alcohol favours its reabsorption. Marzioli (quoted by Lo Monaco), in the belief that this toxic effect is mainly caused by the formation, in the intestinal tract, of ammonia from the calcium cyanamide, recommends acid drinks. Examination of the nasal cavity has not given positive results. The explanation put forward by Hesse of a combined action may, perhaps, be considered the more probable. Nevertheless, there are still specific effects not so far fully explained.

The toxicity of dicyanamide is one third of that of cyanamide. Absorbed by the digestive tract, it is slowly decomposed in the intestinal tract in such a way that only a relatively minimal quantity of cyanamide circulates in the system. Excretion is effected in the form of urea.

**STATISTICS**

Little statistical evidence exists as to the morbidity of workers on nitrolime. In a hospital where many such persons applied for treatment, Koesch noted 50 cases of dermatoses (5.42 per cent.) during the four years prior to the opening of the factory, and 102 cases (4.59 per cent.) during the four subsequent years. He counted 90 cases of inflammation of the respiratory organs among the 448 patients in four and a half years.

An enquiry of E. Fabri’s in 1913, in a cyanamide factory at Terni, dealt with some 300 workmen with 3 years’ duration of employment. The industry in question, which was considered by Fabri to be in a condition unfavourable to the health of the workers because of the dust given off, especially in grinding and bagging, quickly set its house in order and the health conditions soon improved. In the grinding department, 4-hour spells of work were introduced and in the bagging department piece work was instituted, but with a wage scale equivalent to an 8-hour spell. Oiling was only done twice a year on receipt of orders. The factory instituted strict medical examination on commencing work and periodically afterwards. Wearing of gloves, goggles, and respirators was made obligatory. The two first-named are without any doubt useful prophylactic measures in the majority of occupational maladies. Sickness rates for rheumatism and influenza were found to stand highest. The humidity of the district and the epidemic prevailing at the time, together with work at the furnace, were accountable for this circumstance. Gastric attacks were common, but Fabri could not attribute them to cyanamide dust. No case of tubercles was found. Inflammations of the nose, pharynx, tonsils, and larynx were numerous, due either to the dust or to rheumatic conditions.

Incidence of infectious diseases of the respiratory tract (especially pneumonia) was very high, and forms of neuritis and tachycardia, without other obvious cause than cyanamide and alcohol, were found. Dermatitis affected the majority of the workers with frequent subsequent attacks so that many workers had to leave. Cases of inflammation of the eyes were not characteristic of cyanamide poisoning. In France, Brissy collected, in his thesis of 1926, thirteen records of injuries due to calcic cyanamide.

**PATHOLOGY**

(a) Lesions of the skin and mucous membranes in practice show a marked polymorphism depending on the site of the lesion and the predisposition of each worker. They occur soon after work has been begun and are favoured by the fact that nitrolime coming into contact with sweat or other moisture present forms a paste mass which sticks to the skin. While slight cases show only erythema, and swelling, moderate ones become the seat of acute or subacute eczema, with blackish colouration of the skin, and the worst cases develop papules, vesicles, and bullae, followed by skin lesions presenting a weeping condition or crusts. Itching is sometimes very troublesome; scratching aggravates and leads to complications with mixed and septic infections. Sometimes the whole body is involved, but the seat of infection is not characteristic. The junctions of the skin and mucous membrane, however, are preferred (corners of the mouth, nostril), the interdigital spaces, the elbow bend and axillae. The ulcerative process, at first clearly defined and separate, assumes, in consequence of scratching and in the presence of moisture, wide extension, especially amongst agricultural labourers who scatter the manure, and gives rise to extensive necrotic patches, blackish in colour, which penetrate deeply, are painful, with heaped-up edges, and very slow in healing. The presence of a grain of cyanamide dust in a small scratch or cut may quickly cause it to assume a serious aspect from the phlegmonous inflammation or even supplicative periostitis induced.

Brissy has described a specific lesion due to calcium cyanamide, which takes the form of an atomic ulcer of the fingers and palm of the hand, in workers who manufacture this product. The ulcer is situated in the folds of the skin and follows a transversal direction in relation to the axis of the member. It is found also, according
to Favre of Bellegarde, on the lateral surfaces of the metacarpal phalanges of the three last fingers, where it takes a more or less circular form. It consists in general of a black hard friable and adherent crust containing debris of the epidermis and grains of cyanamide. When removed there appears underneath fairly deep and conical ulcerations painful at the root. The evolution is fairly long, but the condition heals easily if the ulcer is protected and treated from the outset. If left to itself, however, it may become infected and give rise to troublesome septic conditions.

The cyanamide causes small inflamed ulcers on the mucous membranes. Among labourers conjunctivitis, rhinitis, gingivitis, tonsillitis, laryngitis, and bronchitis are frequent. Koelsch has never seen in factory workers irritation of the eyes or its sequelae (such as ophthalmia, keratitis, or ulceration of the cornea), although they have been described in husbandmen as a result of the dust getting into the eyes or of rubbing them with soiled fingers.

(b) The headaches of which many of the workmen complain would alone seem to indicate general disturbance, slight in importance but manifesting itself particularly in a special localised congestion affecting the upper portion of the body. The skin of the face, neck and scapular region assumes a deep red or bluish colour (as when very heated or excited), most frequently with a bright red scarlatiniform-like rash on the arms and trunk extending in some cases below the collar bone as far as half way down the sternum, and on the back as far as the spine of the shoulder-blade. This redness (mal rouge) is typical of acute poisoning by calcium cyanamide, just as lead colic is typical of an acute crisis of lead poisoning. In some cases this colouration descends lower. The redness may be uniform with toothed edges, rarely with healthy zones of skin between, or may take the form of more or less large blotches. The scleroties are strongly injected; the lachrymal secretion appears increased; the mucous membranes and the membrane of the palate and the pharynx are very injected. No noticeable rise in temperature occurs corresponding with the erythematous portions of the skin; on the contrary, the hands very often seem to be cold and the whole body a prey to slight tremor (cold shivers). The respiration rate is a little increased, thoracic, and often broken by deep inspiratory efforts easily detectable by the ear, as well as a slight cough; the pulse is rapid (100 to 130 a minute). Sometimes acuity of hearing is diminished by reason of the strong pulsations in the ear; blood pressure is generally lowered. The differential count of the blood is normal. (For spectroscopic examination, see above.)

In severe cases there is slight vertigo, tremor and jactitation, probably of psychical origin and noticeable in susceptible persons (weaklings and women). In general cases are slight, but are more severe when large quantities of the dust in question have been absorbed (and this is equally so in the absence of alcohol). The symptoms on the contrary are very noticeable in practically every person who has taken alcohol in any form at the same time or shortly before or after the absorption of the dust. If there has been intermission from work for a day or two or longer, alcohol can be taken without risk of congestion, but if contact with cyanamide is continued the reaction appears again on taking alcohol. Acclimatisation apparently does not take place. Individual predisposition is undoubtedly necessary. Nevertheless, all the workers, almost without exception, are susceptible to some degree.

The duration of the attack varies and depends mostly on the amount of alcohol taken; generally it lasts one or two hours. Vomiting almost immediately improves the condition and lessens the redness. After the attack is over, there is slight collapse and shivering. So far, sequelae have not been observed, nor do the attacks get worse although duration of employment may have been long. No chronic effects even after many years' exposure are known.

Diagnosis rests on knowledge of the kind of work performed. The dermatitis and irritation of the mucous membranes are hardly specific; on the contrary, the greyish black crusts are distinctly characteristic. The general symptoms, however, are so definite as to be unmistakable. Strangely enough, the action of animal charcoal, combined with that of alcohol, causes the same congestions (Moench).

Demonstration

Shake urine vigorously with ether, add some drops of ammoniacal silver solution. Dissolve the yellow precipitate obtained (insoluble in ammonia) with nitric acid and titrate with a solution of sulfocyanate of ammonia.
HYGIENE

So far as treatment is concerned, the dust adhering to the skin and superficial mucous membrane should be removed by careful sponging with oil and petroleum benzine. Washing with soap should be avoided. The treatment for the itching and acute eczema, etc. is that appropriate for eczema generally.

Now that the workpeople know the causation and symptoms, medical interference is hardly ever called for. In severe cases rest for some hours is advisable, and the face, should be smeared with oil and vaseline. The German Association of Dealers in Nitrogenous Manures has prepared a cautionary notice on the subject of the scattering of nitroline. Goggles and means of protecting the nose are recommended, also stout shoes, protective overalls, with jackets and hoods capable of being fastened in such a way at the wrists and ankles as to cover the body completely. If no overall is worn the clothing needs to be closely buttoned up. The uncovered parts of the body, particularly the hands and the face, should be smeared with oil and vaseline. Scattering should be with and not against the wind. Persons with any cut or scratch should not handle the material, nor should those who are subject to respiratory affections. Hot water for washing should be available.

LEGISLATION

No special regulations for the manufacture of calcium cyanamide exist, the preventive measures prescribed against dust being sufficient. Should the use of calcium cyanamide become more widely practised in connection with the technical production of synthetic chemical products (urea and its derivatives), the want of legislative measures in relation thereto would have to be remedied. In fact where carbides, acetylene, particularly bad carbides containing compounds of lead, arsenic and sulphur, etc. are used in the chemical industry in question, the workers are in danger of exposure to phos- phurized hydrogen, arsenic, etc., as well as to that of explosions. So far as the work of women and children is concerned, see the measures laid down for chemical manure factories.

The lesions and effects set up by cyanamide are brought under the Workmen's Compensation Act in Switzerland.

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Camphor (Synthetic)

French: Camphre artificiel ou synthétique; Camphène. — German: Camphilen; Künstlicher Kampfer. — Italian: Camfora artificiale o sintetica; Camfene. — Spanish: Alicantar artificial.

This product has the same chemical composition as ordinary camphor (C_{10}H_{16}O), but it is produced artificially. There are various methods of preparing it, but essence of turpentine is most generally employed as the basis of synthetic camphor, the essence being extracted by steam from the resins issuing from incisions made in pine trees. They are composed of terpene hydrocarbons: C_{10}H_{16}. The pinenes are a constituent of maritime pines. The transition from pinenes to borneoles and isoborneoles can occur by two different processes (by passing through the stage of camphenes). From the borneoles and isoborneoles, camphor is obtained. During this operation there is liberation of nitrous fumes which are recovered. Direct transition from camphene to camphor has also been effected industrially by greatly simplifying the process.

Synthetic camphor is in the form of a crystalline powder, which is sometimes compressed and which possesses the same properties as ordinary camphor, except that it has a less fragrant odour. It is manufactured in France, Germany, Great Britain, the United States, etc.

Medical literature records the death of a German worker whose duty it was to attend to the heating of containers in which synthetic camphor was dissolved. Trismus in such a pronounced form was present that efforts to unlock the jawbone after death, even with the aid of an instrument, failed.

Professor Lewin finally investigated the case, and found during personal inspection of the conditions that even short exposure to inhalation of the fumes escaping in small quantities from the cover of the container aroused in him a feeling of oppression in the chest, and after the lapse of two hours caused slight faintness, so that the product could not be characterised as perfectly harmless. Artificial camphor, when pressed into the blood stream in sufficient quantity from the stomach, rectum subcutaneous tissue, or lungs, can cause the same functional disturbances as the natural camphor. The hair of the worker in question smelt strongly of camphor three days after death, proving exposure to strong fumes. Poisoning probably occurred rapidly, the strong fumes evolved in presence of heat accelerating the invasion of the brain and spinal marrow by the camphor.
Candles (Manufacture of)

French: Bougies. — German: Kerzen. —
Italian: Candele. — Spanish: Buñas, Can-
delas, Velas.

Candles are cylinders of combustible materials provided with a little wick in the centre by which the candle is lit and burnt.

A good candle should burn without smoking and without smell, tranquilly and without flickering. When it is blown out the wick ought to become extinguished suddenly without smoking. A candle ought not to soften under ordinary conditions of temperature. When it burns, the matters of which it is made should form a liquid which can be drawn up easily by the wick, ought not to run, and, once the flame is extinguished, ought not to be filled with melted matter.

RAW MATERIALS

The wicks are made of threads of cotton plaited loosely. The body of the candle is made of the following substances:

Stearic acid, a fatty acid (formula, C₁₇H₃₅COOH) which melts at 70° C., and is the principal constituent of animal grease and fats. Formerly tallow was also used, but this is abandoned now as it burns with a smoky flame and gave off an unpleasant smell.

The hydrocarbons, used either alone, or mixed with fatty acids. These are: paraffin, a mixture of solid hydrocarbons, for which a basis is, white, translucent, chemically inert, without smell or taste, and insoluble in water. The superior hard qualities melt between 56° and 65° C.; the 50° inferior at from 30° C. Paraffin burns without smell and gives more light than stearic acid and beeswax.

Ceresine (ozokerite, mineral wax) is a solid residue from the evaporation of petrol, resembling beeswax, but is less crystalline than paraffin. It melts at 60°-70° C. and gives a smoky and scintillating flame.

* Montannine * is a white substance, prepared from bitumen as the starting point and extracted from lignite and is extracted from sperm oil. It consists mainly of cetyl palmitate (palmitate of cety); it melts at 44° C.

Beeswax, obtained by melting, purifying and moulding, and sometimes by pressure, is of a yellow colour; it whitens in the air and under the action of oxidising agents (nitric acid, chromic acid, oxygenated water). The yellow wax has a smell of honey; white wax is without colour or taste. It melts at about 63° C.

Spermaceti is a white wax; it is crystalline and is extracted from sperm oil. It consists mainly of cetin (palmitate of ceti); it melts at 44° C.

Carnauba wax is a vegetable wax which is collected from the leaves of a wax-palm of Brazil (corypha cerifera); it consists mainly of myricyl cerotate. It melts at 84° C.

The waxes such as beeswax, carnauba wax, and sperm wax are used to make candles de luxe; the other products are used for ordinary candles.

INDUSTRIAL PROCESSES

The type of manufacture described is the ordinary one of stearic acid.

Preparation of Stearic Acid and Fatty Acids

These bodies are extracted from animal fatty matter by saponification. But as most of this matter contains, besides solid fatty acids, liquid fatty acids (oleic acid), there is advantage in increasing the yield in solid acids by a preliminary hydrogenation of the fatty matters. In saponification by lime, the suet, heated in an autoclave provided with stirrers, is mixed with water and milk of lime or magnesia. The fats become hydrolysed into glycerine and fatty acids. When the process of saponification is finished (it is controlled by repeated analyses), the product is allowed to stand. The mixture separates into several layers, the uppermost consisting of liquid fatty acids and the next of glycerine, and the lower of insoluble calcareous soaps (stearates, oleates, and margaricates of lime) coming from the partial combination of the free fatty acids with the lime. Decantation follows. The glycerine is recovered separately; the liquid fatty acids are distilled with steam; the insoluble calcareous soap is treated while hot with sulphuric acid. Sulphate of lime is thus obtained while the melted fatty acids collect in the upper part. If they are too black they are redistilled by steam; if they are sufficiently white, they are washed with boiling water and are cooled in cakes.

After purification, the fatty acids are led into cast tin trays placed one on top of another in cooling chambers, maintained at a temperature such that crystallisation takes place slowly (10-12 hours). The crystals of stearic or palmitic acid are then of sufficiently large bulk and retain in their network the oleic acid.

When there is no oleic acid the stearic acid obtained can be used directly for the manufacture of candles. If there is oleic acid, this must be got rid of to obtain an acid with as high a melting point as possible. The mixture is then pressed cold (50 atm.), at a temperature of 50° to 60° C. The oleic acid flowing away still contains solid acids (stearic and palmitic) in solution. These acids are left to
crystallise out in well-cooled cellars; they are drained through woollen sacks, and mixed with crude acids. The residual oleic acid is used in the manufacture of soaps or of hydrostearic acid.

The fatty acids pressed into cake form are still slightly coloured at the edges. These portions are removed and used in another process. If small quantities of lime or oxide of iron soil them, these impurities are removed by treatment with sulphuric acid. The fatty acids melt and give up the iron, while the lime yields to the sulphuric acid. They are decanted and washed with hot water until every trace of acid has disappeared. A second melting takes place before they are used for the manufacture of candles.

Saponification by Sulphuric Acid

This is the process utilised for grease and fats of inferior quality (garbage, putrefying bones) or poor in fatty acids, as well as for the final treatment of the fatty acids obtained by the preceding process. In the Milly process the melted suet and sulphuric acid (at 66° B.) are first mixed, and the whole is brought to 30-35° B., while the whole is stirred. The fatty acids are freed; one part of the glycerine of the fatty matters is converted into sulfoglyceric acid, and at the same time sulfo-fatty acids are formed which are decomposed by boiling water. The sulphurous gases which come off are collected separately.

Distillation by superheated steam, formerly practised, is replaced to-day by distillation under a vacuum.

In the Droux process the fatty acids, after preliminary drying, are distilled under a partial pressure in a retort with the aid of superheated steam (260-360° C.). Stearic acid, mixed with margaric and palmitic acid, is collected, and, if there has not been preliminary hydrogenation, a fairly high proportion of oleic acid.

Preparation and Colouring of the Mixture

The stearic candles, made generally with a mixture of stearine and paraffin (50 per cent. of each), to which has been added a little ceresin or carnauba wax to lower the melting point, have a yellowish colour, which is first corrected by addition to the paste of blue colouring matter (methyl violet, Prussian blue). For coloured candles, organic dyes soluble in alcohol are used because these least affect the burning of the candle. For red, use is made of Sudan IV, flexin, Bengal rose, rhodamin; for yellow, chinolin yellow, auramin; for blue, indulin, Prussian blue, methyl violet, and even chromate of lead and white lead have been used. The mixture is melted at about 65° C., the colouring matters being added by stirring.

Preparation of the Wicks

These are made before moulding. Cotton threads are loosely plaited together and then dipped in an acid saline solution (boric acid and sulphuricchloride, ammonium sulphate or phosphate; chloride or nitrate of potassium). The plaiting brings about theshrivelling up of the wick when burnt so that the extremity burns without smoking. The chemical solution vitrifies the ash of the wick and the minute particles of glass leave the end of the wick free for the ascent of the wick when burnt. In the absence of this chemical treatment the wick burns short in the flame causing a persistent flickering.

Moulding

The machines for moulding the candles consist essentially in one or several batteries of moulds, kept in a metal box into which, at will, hot or cold water can be made to pass. Each mould is made of tin through which passes a piston which can be lowered or raised. The wicks rolled round bobbins at the lower part of the apparatus pass along the axis of the piston and the centre of the mould to end in the candles of the preceding batch, which are kept in place by special clamps.

After the hot water has been let into the box to warm the moulds, the candle material is passed in in quantity greater than that necessary to fill the moulds, in order to make up for the contractions due to cooling. The moulds are then cooled by introducing cold water, which solidifies the candles. The preceding lot of candles being held above by the special clamps, the wicks are cut through and the bundle is detached. The excess of candle material is removed by scraping with a special tool. The candles which have been made are ejected into the trough, placed above the moulds, which carries
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the wicks. The pistons which were pushed up for this ejection are pulled down and the cycle of operations recommences. Some moulding machines, of a relatively simple character, instead of delivering a finished candle, only make the cylinder with the mesh in the middle. In such a case, after the moulding, the candles in cylinders require to be cut of equal length and weight, and the base has to be modelled (in smooth or fluted conical form).

When the candles are finished, they are bleached by exposure to air, then polished by rolling between two plates of walnut wood, very smooth, and cleaned with woollen rags, next trimmed to remove mould marks, marked, and then packed.

Paraffin Candles

These are made as has been described, but with a paraffin of high melting point (50° C.). They are white and smoky, which distinguishes them from stearin candles. The flame is smoky, especially when they are prepared with paraffin of low melting point.

These candles are generally made of a mixture of paraffin and stearic acid (3 to 15 and even 33 per cent. of the latter), which raises the melting point. Minute quantities of carnauba wax or stearin, which raises the melting point, are sometimes added. The transparent candles made of 100 parts of paraffin and 2 parts of beta-naphthol, melt at 80-90° C., and yield a mixture which remains transparent after moulding. Other mixtures contain: paraffin, 70 or 90; stearin, 15 or 5; petroleum, 15 or 5 to 100 parts of the mixture.

Spermaceti Candles

These are made especially in Great Britain or North America with refined sperm whale oil, to which is added 5 or 10 per cent. of paraffin or white wax. They are white, semi-transparent like alabaster, and are luxury articles costing a high price.

Wax Candles

Wax candles are rarely made from pure beeswax, but often with a mixture of beeswax and a more or less important quantity of cere sine, paraffin, etc., or still more often, a mass made of these substances inside and coated on the outside with wax or a mixture of wax (60 per cent.) and paraffin (40 per cent.). These candles are made also by moulding or ladling by pouring the wax or melted mixture on to the wicks stretched on hoops turning above the copper containing the melted mixture. This operation is repeated until the wax has attained the desired thickness. This is in this way that church candles are made.

The method of immersing the wicks repeatedly into the wax or mixture is sometimes employed. The candles then are formed of concentric layers.

In the method with a perforated plate for moulding, the wick, of undetermined length, passes into a bath of the molten material, then successively through perforated plates of larger and larger diameter until the requisite size is reached.

PATHOLOGY

The question of whether the emanations given off in the manufacture of candles are injurious or not to health is still an open one. Some writers maintain that the olfactory organs alone are affected, and show statistically that the duration of life of workers in these factories is generally above the average, forgetting that the weakly avoid such occupations.

The causes of injury to health are to be found in the volatile fatty acids which are given off in the course of the melting of the fatty matters: acetic acid, butyric acid, cyanhydrates of ammonia, pyridine, picoline, etc., sulphurised hydrogen, etc.

Among the symptoms noticed in these factory workers are cata rhal or chronic laryngitis, due to the irritation from the fatty vapours and to the brusque changes of temperature; bronchitis due to the same causes; subacute and chronic affections of the digestive tract, catarhal jaundice, which are ascribed to the ingestion of alkaline vapours neutralising the gastric juice and thus hindering digestion. The vapours and fatty acids are even said to be the cause of injury to the stomach, which may go as far as pyloric ulceration.

Less doubtful and more frequent are the lesions set up by the fatty acids on the ocular conjunctiva and skin. Blepharitis, conjunctivitis, as well as eczemas of various kinds, have been described due to the irritating action of the alkalis and fatty bodies, acids, and etheric oils. One particular form of eczema (umbilical and abdominal) is attributed to the carrying of melted substances and fatty acids in trays supported on the stomach without intervening impermeable aprons.
HYGIENE

The workrooms should be constructed of impermeable materials, especially the walls and floors. The floor should be fluted and sprinkled with sawdust to absorb the fatty matters. Cleanliness must be strict; the floors and walls periodically washed. There should be good general ventilation with use of efficient closed apparatus. Precautions must be taken against the diffusion of smells and vapours, by means of hoods and chimneys. Precautions require to be taken against danger of fire. The vapours and gases given off in the manufacture should be destroyed by burning them (over hearths in special apparatus). Furnaces and boilers must be situated outside the workrooms. Inside the factory provision should be made for keeping fine sand to put out commencing flames. Steam should be used for heating the distilling apparatus. Use for firing of waste impregnated with fatty acids should not be allowed.

Tallow should always be melted over a water bath or by steam — never over a naked flame. Purified fats only should be used. The workrooms for storing the raw materials should be kept separate from those of the finished articles. Decaying refuse should not be allowed to accumulate, but be burnt. All residues likely to cause bad smells should be removed as frequently necessary, every day. The residual waters should be collected in a special reservoir. They ought not to be turned into the sewer before complete neutralisation. They can well be removed in hermetically sealed barrels.

While processes calling for the use of such antiseptic products as vinegar, alcohol, etc., are used less and less and are limited to special cases, modern methods make use of desiccation, salting, smoking, freezing, and, above all, of sterilisation.

TECHNICAL DATA

This article is confined to an examination of the preparation of food in cans; the reason being that, thanks to the perfecting of appliances and to the increasingly extended use of automatic machinery, this industry has assumed a great importance. It includes the preservation of fish, to which must be added in the case of some countries, e.g. United States, the preservation of oysters and shell fish, meat, vegetables, condiments, sauces, and pickles.

Preservation of Fish

This is carried out by several processes:

(a) Drying, applied especially to cod prepared in the fresh state on ships and sold on return. The fresh cod is washed and dried either in the sun, stretched on screens or hung by the tail to wooden brackets, or in stoves.

(b) Smoking is used for herrings and for salmon. The fish are put in barrels with brine, then taken out after a fortnight, washed, threaded on small sticks, hung in the fuming chambers, which are low ceiled rooms or galleries underground, where they remain exposed to the smoke. After smoking the herrings are oiled and put in barrels or small boxes.

(c) Salting, or preservation in brine, used for herrings, sardines, and anchovies. The fish have the fat removed and are scaled; next the head and tail are cut off. Then follow cleaning, gutting, removal of bones, putting in brine, draining, and putting in barrels. On reaching the works the salt fish should have the bath of saturated brine renewed daily.

(d) But the process of preservation most employed is canning fish, a process which is based on the well-known method of Appert — boiling in receptacles and then hermetically closing.

The sardine industry is the most extensive and flourishing; the season lasts from May to November.

The sardines reach the factory in boxes, each of which holds 250 sardines and are then subjected to a series of operations. The heads are removed by means of special scissors, which at the

Canning and Food Preserving Industries


The preservation of food to-day is no longer carried on according to ancient and empirical recipes, which, as a rule, robbed the products treated of their natural appearance and flavour, but rests on a scientific basis which enables skilled workers in this industry to protect vegetables and fruit, meat, and fish from microbial changes, and, at the same time, to preserve all their nutritive qualities.
same time remove the guts, thus cleaning or gutting. After passing through brine, the fish are washed and put on screens of tinned wire, tail upwards in cages of galvanised wire, in divisions and put to dry in the sun for three hours, or in chambers heated by steam (tired and cleaned). The meat, ragout, potted meat, or potted liver is put in a can, which is filled with a sauce or prepared gravy; the remaining operations are done as in the case of preserving fish.

For making meat extract, the meat is chopped, boiled with its weight of water, then drained and pressed. The liquid, after the fat has been removed, is evaporated over an open fire, then concentrated in vacuo and put into pots or jars, which are subsequently sealed down according to the usual technique.

**Preservation of Vegetables**

Dry vegetables such as beans, peas, and lentils, after picking over, sorting, and cleaning, are dried in a hot-air stove.

In the preparation of dried vegetables, these are washed, picked over, cut in shreds, and treated in an autoclave at 115° C., or are simply scalded by immersion in boiling water for a short time; then they are dried in a stove and put up in packets. In order to make compressed vegetables, they are cut into shreds, and then dried at a stove; next they are compressed with a press and then sawn into tablets.

**Salting** is used for some vegetables—for the making of sauerkraut in particular. The cabbages, divided into quarters, are cut up by machine or by hand; then they are put into casks in layers alternating with layers of salt. The casks are closed with double bottoms and tightened by a screw press.

The preparation of canned vegetables, i.e. vegetables "au naturel", is concerned chiefly with green peas, French beans, dwarf kidney beans, artichokes, asparagus, tomatoes, mushrooms, and truffles.

The manufacturing processes are as follows: first comes preparation of the vegetables; here green peas are shelled and sorted by hand or better still by machine; French beans are cut into strips and sorted; asparagus is peeled or scraped, cut to one length and sorted according to size; tomatoes are left whole or cut in two (tomatoes for stuffing), or crushed into puree, and after a little cooking passed through a sieve; mushrooms are skinned and washed; truffles are skinned and brushed.

For French beans machines have been invented which cut them into lozenge shape, lengthwise, or obliquely. Preserved spinach and sorrel is prepared by machine choppers and strainers, whilst potatoes, carrots, or onions are peeled with other machines.

In the same way, by means of special turning-boxes cabbages are perforated
and the bottoms are removed, and leaves are trimmed off artichokes.

Blanching is then carried out by light cooking in boilers for a short time (five to eight seconds). This operation requires careful watching and handling. Copper sulphate is added to green peas and French beans to preserve their green colour.

The baskets of vegetables when taken out from the boilers are put into vats to cool, which is effected with cold water. Then follows canning or bottling, depending on circumstances; juicing, which consists in pouring into the cans filled with vegetables juice from the cooking, or a juice prepared separately; and finally the sealing of the cans.

Fruit Preserving

Some fruits consumed as condiments are preserved in salt; for example olives are put into cans in alternate layers with salt. Others are preserved in vinegar: thus capers, gherkins, cucumbers, onions and various mixed pickles are prepared generally by vinegar makers and makers of mustard.

Sweet fruit is preserved in its natural state in juice or syrup. The fruit picked over, stoned, topped and tailed when necessary, is sorted and then scalded with hot water; canned or bottled; after juicing, with juice from the cooking, or a special syrup, the sealed cans or bottles are put into the autoclave at 110°-120° C. for half an hour.

For making fruit pulp the fruit, after being washed and cooked by steam, is crushed and reduced to pulp, which is cooked again, put into moulds and dried in a stove.

Fruit preserved in brandy is chiefly prepared by dealers in spirits or confectioners.

When the factories are not able to deal at the same time with the whole crop, say, of cherries, for instance, part of the fruit is passed on for sulphuring. The small cages full of fruit are stacked on their arrival in brick chambers in which sulphur is burnt; there they are left for about twenty-four hours. The decoloured fruit is then put into open vats filled with salt water, which covers them completely.

Sources of Danger

The hygiene of the industry in preserved foods has been improved in large towns; it is, however, still far from satisfactory in some rural preserving and wherever primitive methods are employed. Among the sources of danger the following must be mentioned: the strenuous nature of the work, with heavy loads to carry, up to 20 to 30 kg., long hours of work, especially as regards some seasonal preserved foods, such as fish, vegetables and fruit, with all their injurious consequences; overtime, night work, and absence of regular meal hours; exposure to moisture: in canning factories the steam is very dense in the workshops, especially in the blanching departments and the cooking, when it condenses on the clothing of the workers. One must bear in mind, in this connection, exposure to inclement weather when certain operations are done in the open air, such as smoking or drying fish or meat. In rural districts where fruit is preserved, the temporary camps put up for the seasonal workers are often the cause of injury to health on account of inadequate accommodation and sanitation.

There should also be mentioned, in some cases, dirty floors which cannot be properly cleaned by washing with water, and work in overcrowded rooms with insufficient available cubic air-space.

In addition to these sources of danger arising from general working conditions, others arise either from the raw materials used, whether meat, fish, vegetables, mushrooms, or fruit, or from certain substances used in canning. Thus, for example, soldering introduces a risk from lead poisoning and from acid fumes.

For some years past, especially in the United States, instead of solder, a solution of india-rubber, resin, and red colouring matter, in commercial benzene, called red clay, is used; this solution is projected into a groove stamped round the top of each can. An automatic machine ensures the evaporation of the benzene, which leaves a thin layer of india-rubber adhering to the bottom of the groove. It is during this operation that injuries to the health of the workmen arise, especially if there is not a good exhaust system for the removal of poisonous vapours.

Finally should be mentioned, danger from the fumes of sulphurous anhydride, as well as from various substances which may possibly be used, e.g. salt, mustard, and vinegar; they may poison and cause painful sores. Risk also exists of burns by hot mixtures and of falls on moist and slippery floors.
PATHOLOGY

The general pathology of the workers in the preserved food industry does not present anything definitely specific. In addition to fatigue due to long hours of work and exposure to moisture, which may cause catarrhal affections, rheumatism, and pulmonary disorders, lessened resistance to infectious diseases is observed and a decided frequency of tuberculosis.

A very detailed enquiry among the personnel of the preserved food industry is that of Harris and Dublin made in New York in 1917.

The most characteristic damage is that caused by handling the food materials. Thus, for example, handling meat may carry with it risk of infection by diseases transmissible from animals to man such as anthrax, bovine tuberculosis, glanders, and actinomycosis, or at any rate to a condition of septic sores and wounds. In the same way the handling of fish may similarly mean a risk of septic punctures. Some cases of erysipelas and erysipeloïd forms have been reported by Klauder, Richter, and Hartrins.

Recently (1927) there have been observed in Germany among 22 out of 48 women workers in a factory for preserving mushrooms, various troubles consisting chiefly of ocular affections, photophobia, mydriasis, defective sight, eyestrain with diminution of visual acuity, and lachrymation due to a superficial keratitis. These lesions were accompanied by disorders which were either general, e.g. fever, or confined to the respiratory apparatus with distressing cough, laryngitis, and bronchitis or to the digestive organs and liver with gastric symptoms, anorexia, vomiting, and jaundice. These conditions were due to helvellic acid, which becomes vaporised in the air in fine droplets when the heads of the mushrooms are washed in cold water.

The handling of vegetables and fruit may cause eczema and dermatitis (see article "Occupational Diseases: Skin"), due to the action of juice and liquid sap.

Thus, for example, in a preserving factory in the State of Brunswick there were reported during 1922, especially during the asparagus seasons, numerous cases of irritation of the skin. In the severe cases it was necessary to prohibit work entirely. In an Italian factory for preserving tomatoes, G. Foa, in 1927, observed several cases of eczema localised to the inner surfaces of the fingers and the interdigital spaces — which very closely resembled itch. Next the eczema extends to the palms of the hands in the form of deep and painful fissures.

Enquiry showed that the trouble was due to acid juice and particularly to citric and malic acids. This small epidemic ceased completely when the women employed in peeling the tomatoes were provided with basins containing a solution of 1 per cent. hydrate of soda for rinsing their hands and running water to wash away any trace of the alkali.

Similarly cases of dermatitis have been met with among workmen handling figs and dried prunes. The lesion was caused by living or dead insects, Carpoglyphus passularum, found on the fruit. (For further details, see article "Skin Diseases").

In the case of a few English workers in the food industry employed in sorting and packing provisions preserved by drying, Ch. Russ in 1923 observed a cutaneous eruption situated on the posterior surface of the forearm. It was due to a ceriopella resembling in appearance an asteroid trichophyton. It is supposed that it was connected with a mould on the sacks imported from the East.

Symptoms of poisoning with lead or benzene have been found among workmen employed in sealing cans.

HYGIENE

Workers employed in the preservation of food should be carefully examined, and all those who show symptoms of contagious or transmissible diseases should be eliminated.

Special care should be given to the construction and maintenance of preserved food factories. The floor of workplaces must be impermeable and constructed so as to ensure sufficient drainage and to prevent the accumulation of waste. Frequent washing down must ensure a thorough state of cleanliness. Gratings to stand on should be provided at particularly damp places. The walls must be smooth and impermeable up to any height liable to be soiled by the food handled. The establishment must be abundantly provided with water. A good system of artificial lighting is very important. Every means should be taken to ensure the most ample admission of daylight. Adequate ventilation is required, either natural or, if necessary, artificial, to remove smells so as not to incommode the workers or the neighbourhood.

Efficient local ventilation must be provided for removing steam, fumes, and various poisonous gases.
The smoking chambers must be made of non-combustible materials. Boilers and apparatus for heating and cooking must be arranged in such a way that the removal of the steam to the outside does not inconvenience the workers or the neighbourhood.

Debris must be placed in closed receptacles which are easy to clean. They must be emptied as often as required. The swarming of flies must be avoided.

Waste and fermentable remnants must be placed in silos or properly drained separate store places.

The supply of water and steam must be sufficient to ensure a sanitary state and head-dresses for women. Provision may be mentioned the wearing of work-vests for work, and for cleaning and washing down, must be pure and fit for use.

All apparatus for washing, boiling, and scalding must be supplied with water from a continuous and plentiful supply. They should be emptied and cleaned once a day or as often as necessary.

Mechanical transport should be employed to reduce fatigue caused by heavy loads.

The use of lead solder should be prohibited, as well as the use of cements or mastics containing benzene. The plan of closing cans by stamping or compression should be adopted; it eliminates any risk of poisoning.

The question of waste water is also important (see article "Industrial Waste Waters"). Water from washing and waste water should be conducted to a drain by underground channels, after having been cleared of solid debris. If such drainage is not possible and particularly when the water is intended for irrigation, it must be evacuated so that the outflow does not stagnate or cause nuisance to the neighbourhood or pollute streams. In some cases recourse may be had to biological purification. Some recent experiments made in the United States have shown the possibility of purifying waste water from factories for preserving fruit and vegetables by decanting and filtering, and so rendering them clear and non-putrescible.

Among personal measures of hygiene may be mentioned the wearing of working clothes, mackintosh aprons, shoes, and head-dresses for women. Provision should be made for the use of the personnel of neutralising solutions to counteract the effect of juices, liquid acids, or alkalis, and of drinking water and of baths.

In rural districts special attention must be given to the sanitary conditions of labour camps.

Medical examination of the personnel should be undertaken on commencing work and periodically.

**Legislation**

Young persons of less than sixteen years are prohibited from work in Belgium, at salting and smoking fish, and at salting and preparing meat; in certain States of the United States at soldering; and in France at soldering of cans; young persons of less than sixteen years and young girls of less than eighteen years in Canada at soldering cans; in Spain women of less than twenty-one years at soldering cans; in Italy, boys of less than fifteen years and women of less than twenty-one years at the sardine industry, and at the treatment of animal waste with the object of rendering its use inoffensive.

Compensation for dermatitis (see article "Skin Diseases"), septicemia, or anthrax, contracted from the handling of meat and food products, is provided in the States of Victoria and Queensland.

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**Cantharides**


The cantharides (Lytila vesicatoria Fabricius) are coleoptera the vesicatory and aphrodisiac qualities of which have been known since antiquity. The majority of these insects are found in Hungary, Rumania, and Southern Russia (which furnishes most of those placed on the market). The harvest is
gathered by shaking the trees on which the cantharides live; they are put in closed receptacles in which they are killed by means of carbon disulphide, chloroform, or petrol fumes. They are then dried in the sun or artificially at a temperature of 40° C. The active principle contained by the coleoptera is cantharidin, which varies between 0.3 per cent. and 1 per cent. of the weight of the dried insect. The alkaloid, which is the anhydride of the cantharidinic acid, is extracted from the powder by means of chloroform and is in the form of colourless crystalline lamellae, insoluble in alcohol, carbon, disulphide, and water, slightly soluble in ether, but readily soluble in heavy oils and alkalis.

The pharmaceutical preparations with a basis of cantharides have caused numerous accidents. Accidents of occupational origin have been reported as occurring amongst druggists and chemists or workers in factories for the production of pharmaceutical products. These consisted chiefly of cases of conjunctivitis and keratitis due to contact with powdered cantharides handled without adequate precautions. Hilbert studied a case of blepharitis and conjunctivitis with slight veiling of the cornea and phlogistic condition of the iris affecting a chemist's assistant engaged in grinding the cantharides with a mortar. In the medical treatise by Zander and Geissler (Lesions of the Eyes, 1884), they refer to conjunctivitis met with among workers engaged in gathering cantharides. Two cases of occupational poisoning by cantharidin were recently reported (1922) by Steiner and Marton Prager, of Budapest.

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**Carbanilide**

Carbanilide is used as an accelerator in the rubber industry and is prepared by making carbon disulphide act on aniline oil. During its preparation there is danger of poisoning by carbon disulphide, which may likewise occur during its utilisation. Serious cases reported, with rapid fatal termination, have all occurred during the manufacture only.

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**Carbon Dioxide**

*(Carbonic Acid Gas)*


**Properties**

Carbon dioxide (CO₂) is a colourless and odourless gas which is present in small quantities (about 0.03 per 100 volumes of air) in outside air, but in very large quantities in certain gaseous emanations from volcanoes and in grottoes, etc. The gas has a specific gravity of 1.529 (when compared with air as unity), at a temperature of 0° C. and 760 mm. of pressure; it is liquefied at a pressure of 36-40 atmospheres at 0° C. It is soluble in water (1 volume of water dissolves 1 volume of CO₂ at 14° C. and ordinary pressure); it is found in nature either dissolved in water, or in mineral waters or in combination with metallic oxides (carbonates: marble, chalk, dolomites, etc.).

**Production and Uses**

Industry produces CO₂ in different ways: by decomposing the natural carbonates by means of sulphuric or hydrochloric acid; by calcining stone to lime, magnesite, etc.; by burning coke, charcoal or heavy hydrocarbons; and by fermentation of sugary organic liquids. In some places also carbon dioxide is used as it is given off from mineral springs. The liquefied acid appears as a colourless and odourless liquid which evaporating rapidly gives rise to a very low temperature and partial precipitation of the acid in the form of white flakes. Liquid carbonic acid may, with or without purification, be compressed by means of special apparatus.

Commercially, it is sold in steel cylinders, provided with a screw-cock, protected by an iron cover, which cannot be uncharged except by means of reduction valves or pressure regulators.

Solidified carbon dioxide is also known (obtained by rapid evaporation of the liquid acid) and appears as a white mass like snow. It melts at 56°7 C. at a pressure of 5 atmospheres and can be kept for some time.

Carbon dioxide is used: in the manufacture of alkaline salts, beer, effervescing drinks, sugar, white lead, and chemical manures; for sterilising worts and other organic liquors; as an extinguisher of fires; as a motive force (to force liquids from the cellar to the bar for instance, to fire torpedoes, etc.); to produce cold indus-
trially; to harden white metal; in metallurgy to send up great jets of steel without having recourse to blowing.

It is used also to combat asphyxia (e.g. among aviators and persons overcome by gas); it is then mixed with oxygen (5 per cent. of $CO_2$ to 95 per cent. of oxygen). It has also been used to preserve perishable products (milk, eggs, butter, raisins, etc.); in freezing machines concurrently with ammonia, etc.; to make freezing mixtures; in analytical and histological work; in different chemical industries; in the manipulations connected with oxydisable products (phosphorous organic compounds); in the preparation of salicylic acid, of pure carbonates, of synthetic urea; in the rubber industry to make an atmosphere of inert gas during vulcanisation, etc.

DANGERS

$CO_2$ is given off either in the course of its production or use, but also, in quantities more or less large, alone or mixed with other gases, in many industrial operations or particular kinds of work; in foundries (of brass and iron, etc.); in brickmaking, lime kilns, glass manufacture, potteries; in the manufacture of soda (Leblanc process), size, yeasts, starch, etc.; in redressing skins; in cellars during the preparation of fermented drinks; in confined spaces, such as silos, submarines, mines, underground railways, tunnels, gas-works, etc. Carbon dioxide is found very often mixed with more poisonous gases; in sewer gas, lighting gas, industrial gases, gases resulting from decomposition; products of combustion; explosives, soldering, acetylene gas, etc. Under these conditions it may be carbon monoxide, sulphuruted hydrogen, ammonia sulphide, etc., rather than carbon dioxide, which constitutes the main danger.

PHYSIO-PATHOLOGY — TOXICITY

Normal outside air contains 0.3-0.7 of carbon dioxide per 1,000 (in volume), but this proportion varies much and can be excessively raised in houses, factories, etc. Pettenkofer allowed for domestic premises a normal proportion of 1 part per 1,000, which in factories might reach from 1 to 4. These figures bear, however, strict relation to the cubic capacity, and above all, to ventilation, humidity of the air, etc. The permissible maximum is now regarded as 1 part (by volume) to 1,000 parts of air. (See article "Air of the Workroom").

Analyses made in the laboratory of Paris have shown strikingly that while the air in Montsouris Park is represented by 30 litres of carbon dioxide per hundred cubic metres of air, the air in the Metropolitan Railway showed 75 litres and in summer 63 litres, while the air in a printing works showed 44 litres and that in a dressmaking workshop 458.

Carbon dioxide normally excites the respiratory senses. The influence of venous blood on the movements of respiration has been known for a long time. An animal breathing a gaseous mixture poor in oxygen or rich in carbon dioxide immediately shows signs of distress (dyspnoea). The same signs can be evoked by making the animal breathe pure nitrogen or carbon monoxide, or a mixture of the two gases, with an insufficient quantity of oxygen, or an excess of carbon dioxide in a mixture containing the natural proportion of oxygen.

The importance of carbon dioxide as a normal exciter of respiration has also been known for a long time and it is certainly greater than that of oxygen deficiency. The organic oxidations take place in the cells themselves; in addition to the gaseous exchange taking place in the lungs there are gaseous exchanges taking place between the blood and the tissues. The experiment of Spallanzani is known, by which he shows the production of carbon dioxide by snails placed in an atmosphere deprived of oxygen. The production of $CO_2$ has been proved also in the various tissues; exchange is more active at optimum temperatures and varies with the state of repose or activity of the muscle, the activity of the organ, etc.

Account must be had, therefore, of the three following phases: tissue respiration, transport by the blood of the agents and gaseous products of the respiration of the tissues, and gaseous exchange of the blood in the pulmonary capillaries. The gaseous exchange effected by the blood can take place from every surface linked up with the respirable medium. It can take place, therefore, from the surface of the skin. According to Scharling, the carbon dioxide exhaled by a youth of 16 years of age weighing 67.7 kg. amounts every 24 hours to 4.34 grm. from the skin, 812.72 grm. from the lungs; by a man aged 28 years, weighing 82 kg., respectively 8.95 and 878.88 grm.

The proportion of carbon dioxide in the arterial blood of a man is about 40 c.c. and is always in excess of the
Carbon dioxide has become considerable. Without removing the carbon dioxide an animal shut up in a closed space will eventually suffer from lack of oxygen in the atmosphere which is not renewed takes on a new combination, and about 10 c.c. combined with the red blood corpuscles.

Expired air contains compared with that inspired less oxygen, and, on the other hand, a very appreciable quantity of carbon dioxide. In deep and rapid breathing, however, the better the aeration of the lungs the less the quantity of carbon dioxide (2.5 per cent. instead of 3 to 4).

While the partial tension of oxygen in the external exchange taking place in the lungs is 15 to 17 per cent. of air atmosphere, that of carbon dioxide in expired air is 3-4 per cent.; in alveolar air it is still higher. Alveolar air is noteworthy in that it contains more carbon dioxide than expired air because a part of the inspired air does not penetrate beyond the large bronchi and is expelled without being altered by expiration.

The mechanism of the pulmonary gaseous exchange is not yet completely understood; it appears, however, that the elimination of carbon dioxide is not due solely to a purely physical mechanism, but active participation of the pulmonary epithelium is involved, behaving thus in a manner like glandular epithelium.

Deprivation of oxygen or accumulation of carbon dioxide in the air breathed or in the blood causes asphyxia by reason of deficiency of respirable air. Under these circumstances hematoisis diminishes, and dyspnoea occurs as a compensatory mechanism to the diminished blood supply, but if this is insufficient asphyxia takes place.

The death of a living organism in an atmosphere which is not renewed takes place when the bulk of the oxygen has been exhausted, but the effect is due also to the accumulation of carbon dioxide. As a matter of fact if a sufficient supply of oxygen is given to an animal shut up in a closed space without removing the carbon dioxide produced during respiration, death supervenes when the proportion of carbon dioxide has become considerable.

Carbon dioxide is not in itself toxic, but its presence in excess in consequence of its excessive pressure in the surrounding tissues offers an obstacle to the elimination of carbon dioxide in the blood; at the same time the carbon dioxide formed by metabolism in the tissues does not enter the blood and tissue suffocation results. Several writers, however, maintain that carbon dioxide is really toxic.

Many experiments have shown that animals can live in atmospheres containing 20 per cent. of carbon dioxide. The gas should be considered as inert — its innocuousness being proved by the consumption of aerated waters, by its use without hurt under pressure (in laboratories), by its injection into the veins (which is said only to cause the death of an animal when the quantity is too great to be dissolved), etc. But account is not taken of the rapid elimination of the gas both through the lungs and the digestive tract (eructations after ingestion of waters aerated to excess).

A man plunged into a closed apparatus filled with carbonic acid gas, with his head outside breathing freely, experiences a sensation of prickling and warmth, followed rapidly by marked prostration necessitating an end to the experiment. P. Bert had observed that birds die rapidly under these conditions and more rapidly than when they are plunged into inert gases (hydrogen, nitrogen).

Carbonic acid does not seem to act on haemoglobin which can fix a certain quantity. This fixation is rather on the proteid matter than on the pigmentary nucleus of the haemoglobin. The new combination does not interfere with the oxygen fixation, but the absorption of this gas is said to be less than in the absence of the carbon dioxide. The combination gives to the blood a dull red colour and exhibits spectroscopically almost the same lines as haemoglobin; only absorption of the green and greenish blue rays is more marked. Hamburger and Botazzi are of opinion that carbon dioxide damages the red blood cells, making them lose important quantities of protein matter.

**Symptoms**

Carbon dioxide also exerts local action on the skin and mucous membrane, showing itself in diminution of the sensibility after transitory irritation. This action is sufficiently noteworthy to be utilised therapeutically (anaesthesia).
A proportion of one to three parts of CO₂ per cent. of air is considered as directly harmful without, however, proof that it is so; 0.5 to 2 per cent. in volume, common long ago in the fermenting vats in breweries (such amounts nowadays are exceptional), do not produce acute symptoms even among those experimenting with them (Lehmann, Bickel and Herrligkoffer). There is no doubt that when the content of the air in carbon dioxide exceeds 4, 5 or 6 per cent. acute symptoms are produced (Emmerich); difficult breathing, feeling of cold, headache, dilatation of the peripheral vessels, and loss of consciousness after a short time. According to Hill (1920) a proportion of 3 per cent. suffices to induce a pretty marked dyspnoea with slight headache; if the proportion is from 5 to 6 per cent. the dyspnoea is pronounced and accompanied by headache and sweating; a proportion of 10 per cent. for a minute only sets up headache, visual disturbances, tremor and loss of consciousness, etc.

Massive doses penetrating into the lungs cause a state of depression and anxiety, noises in the ears, syncopy, slowing of the respirations and cyanosis; the extremities become cold and death supervenes.

A proportion of 0.5 per cent. breathed for a long time causes real discomfort, which is more marked and rapid in an atmosphere containing a proportion of 1 per cent.; a proportion of 10 per cent. renders the air insupportable. According to P. Bert about 82 grm. of carbon dioxide are required to kill an adult weighing 60 kg.

There is no proof that small daily minimal doses acting several hours exert any chronic toxic action.

Murrer has proved that a proportion of 2 per cent. in the Silesian mines is without appreciable effect.

In an English coal mine 4.56 per cent. has been found at the ground level and 1.21 per cent. at the coal face; in submarines a proportion of 3 per cent. has frequently been registered and in caissons, where work is very trying, 1 per cent. or more. It must, however, be remembered that here it is the partial pressure which is of importance and not the percentage. Really 1 per cent. of carbon dioxide, for example, at a pressure of 3 atmospheres is equivalent to 3 per cent. at 1 atmosphere. At 2 atmospheres the ventilation in the diver's helmet ought to be double that at 1 atmosphere; at 3 atmospheres it ought to be three times as great, etc.

**Statistics**

For a long time past cases of death have been known where people have been packed together in too confined a space: of 146 prisoners shut up during the war in India in 1756, in a room where the air only entered through a narrow opening, 123 suffocated in less than 12 hours; the prisoners shut up in vats and baskets for terrace of the Tuileries in June 1848 died under analogous conditions, etc. In these cases the toxicity of the confined air was due mainly to the carbon dioxide, but, as may be seen in another article ("Air Control in Workrooms"), to other factors as well.

Although frequent cases are reported of malaise, slight poisoning and, more rarely, deaths from asphyxia in vats, wells, pits, graveyards, soils made up from organic matter (giving rise to the poisonous gases: Irregularly), mines, quarries, grain cargoes, silos, fermenting vats (wine, beer, cider and sugary liquids in general), incandescent mantle factories and generally wherever gas is burnt, etc., it is not always possible, however, to give statistics of cases of carbon dioxide poisoning. Such cases take on generally an acute form bringing about the death of the victim and sometimes that of the would-be rescuers.

As an indication of the number of cases of poisoning, the following figures for Great Britain may be cited: 1913, 12 cases (1 death); 1914, 3 cases (1 death); 1917-1919, 9 cases (6 deaths); 1920, no cases; 1921, 5 cases (4 deaths); 1922, 1 case; 1923, 10 cases (2 deaths); 1924, 5 cases (3 deaths).

**Demonstration**

As to methods for doing this, see the article "Air of the Workroom." Reference should be made here to the fact that generally a candle flame is used to judge of the poisonousness of confined air, or of air vitiating by carbon dioxide. This flame becomes extinguished in atmospheres where the proportion of carbon dioxide is insufficient to cause immediate danger of asphyxia; similarly, an animal in a cage (such as a bird or guinea pig) can be introduced into a supposed toxic atmosphere. American authorities allege that it is defect of oxygen in a mixture of injurious gases rather than increase in the carbon dioxide, which is the main factor in extinguishing a flame, as well as in affecting human beings.

The flame of a match or an oil lamp is extinguished when the proportion of oxygen falls to about 17 per cent.; that of an acetylene lamp at a proportion of 11-12 per cent.; Burrell and others, of the United States Bureau of Mines (1916), have shown that the flame of a oil lamp goes out when the proportion of oxygen is 16.3 per cent.; with carbon dioxide the same result is obtained with a proportion of 10 per cent. (which corresponds to 17.1 per cent. of oxygen).

Whatever the proof may be, the fact remains that if a flame goes out it means that the air is dangerous for man.
HYGIENE

The ideal from the hygienic point of view would be to ask for a maximum limit of one part per thousand of air (by volume); this quantity, however, should not be taken alone, but always in conjunction with the cubic content and ventilation of the room (see the articles "Air of the Workroom"; "Ventilation").

LEGISLATION

In Greece, employment of young persons under 16 and girls under 18 in factories using compressed gases is prohibited; in Italy, all boys under 15 and women under 21; in Switzerland, young persons under 18, when use is made of apparatus under pressure, etc.

In New Brunswick and Ohio, compensation is provided for injury caused by carbon dioxide.

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Carbon Di-(or Bi)-sulphide


CHEMICAL PROPERTIES

Bisulphide of carbon, formula CS₂, is an acid anhydride or a sulphur anhydride, which, when purified, appears as a limpid, very mobile liquid, strongly refractive, almost colourless, with an ethereal smell resembling chloroform. In the crude state its yellowish colour is deeper the more impurities it contains. It then gives off a smell like rotten eggs. Its density is about 1.28 (at 20° C.); it boils between 46° and 48° C., giving off at an ordinary temperature abundant vapour very much heavier than air (1: 2.23 nearly) and thus it tends to collect at low air levels. If evaporation is rapid (as, e.g., by passing a current of air through it) its temperature falls to —60° C. (utilised in consequence for the production of cold). Extremely inflammable carbon bisulphide burns in the air, forming sulphur dioxide.

In ordinary air it takes fire at about 170° C. (Holleman says 232° C.). There is need, therefore, for every precaution in the packing, storage, and manipulation of the product.

The vapour readily ignites; hot metal (hot tubing, etc.) and even electric sparking can make it explode when the mixture of vapour with the air reaches 0.063 grm. of carbon bisulphide to 1 litre of air. It explodes also under the influence of detonating agents, of shock, but in such cases the explosion does not propagate itself. According to other authorities, air saturated with carbon bisulphide vapour constitutes an inflammable, but not explosive, gas.

Only slightly soluble in water (1 litre of water dissolves, at 0° C., 2.904 grm. of carbon bisulphide); it readily mixes with most of the commoner organic solvents in all proportions; alcohol, ether, ethereal water, solutions of phenol and chloroform, etc. It is soluble to 60 per cent. in oil.

It is a powerful solvent of certain substances which are insoluble in most others, such as fats, oils, waxes, resins (except lacquer), India-rubber, sulphur (dissolves its own weight of sulphur at 38° C.), white phosphorus, iodine, and a great number of inorganic substances.

It does not attack, or only very slightly, copper and zinc utensils at the temperature at which they are used for the extracting of fats, sulphur, and other substances.

Bisulphide of carbon undergoes change when stored especially under the influence of light (demonstrated by Berthelot) taking on a yellow colour and yielding an impure bisulphide of carbon.

INDUSTRIAL OPERATIONS

It is found in a natural state in coal tar and in grains of black mustard.

Industrially bisulphide of carbon is prepared synthetically by direct passage of sulphur vapour over carbons (charcoal or coke) at cherry red heat (800—900° C.), so that 88 to 90 per cent. of the sulphur becomes fixed. It is important to have the charcoal well heated before the sulphur vapour is passed over it.

Ordinarily it is made in steel cylinders or in iron or fireclay retorts heated in the usual way. The steel cylinders are arranged vertically in a furnace, provided at their lower extremity with a grill containing a chamber into which the sulphur is introduced by means of special tubes when all is ready. The whole is heated on a hearth and the sulphur vapour given out passes through the red-hot charcoal. The bisulphide of carbon is liberated and condensed in a series of receptacles half filled with water. This process is a discontinuous one and cannot be used for large quantities.

In other processes (Singer, Peroncel, Eckett apparatus) the sulphur is vaporised first and then led over the charcoal heated to redness.

By Taylor's process (see Thorpe's Dictiona ry of Applied Chemistry, 1921, Vol. II, page 77) the manufacture is carried out in an electric furnace with continuous production on a large scale and with great advantages as regards both convenience and safety. The furnace consists of a crucible in which four
Electrodes are placed on two perpendicular diagonals with a cylindrical hearth and a dome.

The last named has a charging flap valve and a pipe for the escape of the bisulphide. The furnace is built of masonry in fireclay bound by iron bands. The furnace crucible is fed with broken carbons and is regularly stoked from above. The sulphur is charged through a hopper, passes down into the retort and melts at the bottom.

The mollen sulphur gives off vapour which passes through the layer of incandescent charcoal producing carbon bisulphide. This then passes through the deep layer of wood charcoal, which fills the shaft of the furnace and gets partly cooled before reaching the dome.

**Purification**

The crude bisulphide obtained at the first condensation contains six to ten per cent. of sulphur, sulphurified hydrogen, sulphur dioxide, methylene bisulphate, various sulphides, carbon sulphurates, and small quantities of inorganic sulphur compounds (volatile sulphides). Purification is effected by lime or iron oxide (Leymann) and by repeated distillation at a temperature as low as possible, over vegetable fat, as the latter fixes the unpleasantly smelling impurities and the sulphur.

The carbon bisulphide, chemically pure, is prepared by distillation over mercury and by drying with calcium chloride.

The necessary purification depends on the uses to which it is to be put later. Storage of carbon bisulphide is effected in iron drums.

**Uses**

Carbon bisulphide is used industrially in a great many processes such as the following:

1. **As a solvent of the fatty bodies in essential oils and resins:** To extract fat from bones intended for the manufacture of animal black, and from coconut oil, oily grains, etc., or oil cake from certain plants (colza, rape seed, sesame, etc.), lanolin; to recover the fats from a large number of industrial residues, animal and vegetable residues; tow and rags (which have been used for cleaning machinery); muddy deposits of oils that have been treated by sulphuric acid, sawdust (that has been used to filter oils purified by sulphuric acid), brown residues from sulphuric saponification before the distillation of fatty acids, grease blackened by use in machinery, kitchen grease residues from the direct extractions of wax; tallow cracklings, residues from the melting of crude and pressed tallow, chemical cleaning of clothes; to degrease wool, skins, meat; to purify crude paraffin (Alcan method); to extract lanolin; to refine tallow from stearine; to extract certain perfumes; to treat spices, and to prepare soluble spices.

2. **As a solvent of other matters:** To extract sulphur from minerals and asphaltic rock bitumen; to dissolve phosphorus, in the manufacture of lucifer matches, of phosphorus for Roman candles, of certain explosives, liquid fire (i.e. solution of phosphorus in carbon bisulphide); for extraction, by solvent action, from tar in numerous industrial processes to remove the sulphur in the purification of gas; to purify potassium cyanide obtained by the Liebig process; to prepare certain wax varnishes; in solutions of wax to cover plaster casts and waxed papers; to dissolve india-rubber (making toy balloons); gutta percha (all rubber cements), rubber for holding air, Chatterton and rubber cements which must dry quickly; for cold vulcanisation of rubber; for manufacture of goods made of thin rubber sheeting; for vulcanising of certain articles or materials.

3. **As a chemical agent in the following processes:** Carbon sesquichloride, prussiate of potash (Gélis process), ammonium sulpho cyanide (to make Pharaoh's serpents). Camphor and different aromatic compounds. cellulose, potassium and alkaline xanthogenates, viscose, artificial silk (in the viscose process), chloride of sulphur, carbon tetrachloride, sulpho cyanide compounds, etc.; to make fire extinguishers and, lastly, as a manure (Hollemann).

4. **As a toxic material (in agriculture):** Against certain parasites and injurious animals (ticks, bugs, phylloxera); to destroy nematode worms attacking the root of beetroot (Molinary); in deratisation.

As a disinfectant and parasiticide it is used in the form of potassium sulphocarbonate which slowly dissolves in the soil giving rise to carbon bisulphide; or it is used in a spray in a 1 in 10 aqueous solution of gelatine.

5. **As a means of producing low temperatures:** It has been used to produce cold, but nowadays this is done by other chemical methods (see article "Refrigerating Plants").

It should be observed that modern technique is replacing carbon bisulphide in quite a number of its appli-
cations by other less harmful substances (e.g. carbon tetrachloride, and generally by the halogen derivatives of the saturated and unsaturated hydrocarbons of the aliphatic series).

DANGERS

The immediate dangers in the use of carbon bisulphide are explosion, fire, and poisoning.

The last named results from inhalation of vapours on contact of the substance with the skin or by its splashing on to the clothes. Conditions which favour its action are high temperature (hot weather, over-heated workrooms, work done stooping or near the floor). Nearly all industrial processes in which carbon bisulphide is used are carried on in closed apparatus.

In order of diminishing risk the industrial processes most affected are the following:

India-rubber industry.— The most dangerous process is cold vulcanisation of rubber, done by dipping the rubber into a solution of sulphur chloride dissolved in carbon bisulphide. The articles are then taken out of the trough and hung up to allow of evaporation in the air either in heated drums or in special drying chambers.

As is remarked in the article "Rubber or India-Rubber Industry", cold vulcanisation is now very little practised. Thus, for example, in Ohio (1920) of 78,000 workpeople only 0.5 per cent. came into contact with carbon bisulphide, and the most affected workpeople were those who made up the solution of rubber, filled the tubes and boxes and carried out the cold vulcanisation of the various objects, etc.

Carbon bisulphide is mostly replaced by dichlorobenzine, methane, carbon tetrachloride, etc. It is used to make carbonilide, an accelerator for vulcanising rubber, resulting from the reaction of carbon bisulphide on aniline oil. The manufacture of this material has already caused a fatality (Hamilton).

Extraction of oil and fats.— This is effected with carbon bisulphide, benzine, ether, etc., in hermetically sealed receptacles (to avoid evaporation), generally arranged as a continuous process.

Preparation and use of cements and mastic.— These dissolved in carbon bisulphide are used to repair shoes (invisible mending) and belts. This work formerly caused mental symptoms known under the name of "folie du cuir".

Preparation of viscose and artificial silk (see the article "Artificial Silk").

Workmen engaged in the manufacture and manipulation of carbon bisulphide are more rarely affected, as the process has reached such a state of perfection that vapour cannot escape in any large quantity. Further, as all the processes are carried on in closed receptacles and by continuous process under every possible precaution to prevent fire and escape of vapour, danger is reduced to a minimum.

Trouble is caused during the manufacture from escape of sulphur dioxide which is given off in large quantities from the retorts when the mixture of sulphur and charcoal is heated to 1200° C.

The nuisance created for the neighbourhood should not be forgotten as a result of the escape of carbonaceous and sulphurous gases coming from the hearths and retorts.

For the sake of completeness mention should be made, as a source of danger, the risk from evaporation from certain large vats and tanks in which carbon bisulphide is stored in a pure state or mixed with other ingredients, in all the operations where the bisulphide comes into contact with charcoal (heating metallic sulphides with charcoal, pyrites, pitch blends, antimony sulphide); heating carbon tetrachloride with sulphur or carbon tetrachlorobromide with flowers of sulphur; dry distillation of anthracite when illuminating gas or benzol has to be removed, formation of gas containing sulphuretted hydrogen by distillation in retorts and subsequent contact with glowing charcoal, etc.

TOXIC ACTION

Facts as to the toxicity of carbon bisulphide date in France from 1851-1860 (work of Payen, Duchenne, Beaugrand), when the Parkes method of cold vulcanisation was introduced. Delpech (1856) was the first to describe the symptoms: his work, which has remained a classic on the subject, was published in 1863.

Some authorities take the view that the toxicity of carbon bisulphide is due more to impurities than to the substance itself, because in the crude state it is notoriously very poisonous; but Lehmann has shown that carbon bisulphide possesses a toxicity of its own — a fact confirmed by numerous other writers.

With animals air containing one-twentieth of its volume of carbon bisulphide infallibly leads to death. Lehmann has shown that 1.5 mg. of carbon bisulphide per litre of air has no effect
on the cat after several hours excepting in signs of fatigue; at the end of eight hours with 2.6 mg. per litre of air its action is pronounced (as shown by inco-

ordination of movement, slight cramps,

paralysis), and still more in three hours

with 4 to 5 mg., in two hours with 7-8 mg., and in half an hour with 10-11 mg. Young animals are more susceptible than old. The phase of depression is always preceded by one of excitation. An animal absorbs about 20.6 per cent. of the vapour of carbon bisulphide which it inhales.

With man Althoff has found that a workroom atmosphere containing 0.7 mg. and even 0.2 mg. has effects on those at work for ten to twelve hours on end. According to Balthazard, acute effects become manifest when the air contains 1.5 mg. per litre of air and a dose ten times less can induce chronic effects in time. According to Lehmann 1 to 1.2 mg. causes headache in a few hours; in eight hours unpleasant effects (mental confusion) lasting for twenty-four hours; 1.5 mg. causes headache in half an hour. With 2.5 mg. effects show themselves quicker; with 3.5 mg. vertigo is present in half an hour and at the end of an hour and a half or two hours sensibility is affected. With 6.4 to 10 mg. a half-hour to an hour suffices to bring about serious symptoms, e.g. impending

narrowing, pins and needles feeling, feeling of deafness, sore throat, irregular respiration, and subsequent headache. A man absorbs about 22 per cent. of the bisulphide vapour he inhales. As regards the setting up of chronic poisoning Luig found that inhalation of 1 mg. per litre of air (0.8 to 1.4 mg., according to the number of days) was highly dangerous, when continued for fifteen days, with an nine-
to eight-hour day's work.

Sensitisation to carbon bisulphide takes place after a first attack. A case is described of a workman who, after having given up his work as a result of poisoning, had a relapse on living with a companion who came home with his clothes smelling of carbon bisulphide.

On the other hand, cases of relative acclimatisation (rare, it is true) have been described in the case of workmen who had suffered on first exposure, but were able thereafter to continue to work without hindrance in an atmos-

phere vitiated by bisulphide fumes. Addiction to alcohol is the most predisposing cause (Beaugrand), so much so indeed as to make some people ask to what extent the symptoms were due to alcohol and to bisulphide of carbon, especially in regard to the symptom of peripheral neuritis.

A first attack predisposes to a second. The persons attacked are said to be badly nourished, neurotic subjects, women (Delpech), and young persons.

Absorption takes place through two channels: the respiratory (from the great volatility of the substance) and the skin. Application even of liquid bisulphide of carbon on the skin causes a sensation of cold, followed sometimes by livel smarting. This substance, after dissolving the layer of fat on the surface of the skin, readily passes through it. Absorption in this way is very important from a practical point of view in the case of workpeople dipping their fingers in the liquid to soak or abstract articles, who often suffer from localised nervous affections in the hand and forearm. It has even been stated that bisulphide vapours collecting in the lower levels of a workroom exercise a local action on the legs and explain the frequent troubles of sensibility felt in them.

Elmination is effected mainly through the pulmonary tract (penetrating smell of bisulphide in the breath) and in the urine. Fehling's solution gives a brownish-black precipitate of sulphide of copper with urine containing carbon bisulphide on moderate heating.

Similarly, elimination of the poison takes place through the sweat and intestinal tract. Elimination is slow, whence a cumulative action, which partly explains the relative slowness in the appearance of the toxic phenomena observed.

Lehmann and his pupils have not detected blood changes either in acute or chronic poisoning such as have been described by some writers. Balthazard states that a destruction of leucocytes takes place.

The toxic action on the nervous system, especially on the peripheral nerve fibres, is favoured by the combination of carbon bisulphide with the nervous substance (analogous to that brought about by chloroform, chloral, and anaesthetics).

Similarly extravasations into the lungs have been observed, into the lin-

ing membrane of the stomach, pneu-

monias, degeneration of the liver cells, and splenic pulp; and lesions of the parenchymatous organs (large glands). Locally, carbon bisulphide has an irritant action. On contact with the skin it causes a sensation of burning and subsequently anaesthesia. It pro-

duces intense congestion of the membranes and a droplet spurting into the eye is sufficient to set up a simple or purulent conjunctivitis (Balthazard).
STATISTICS

Cases of poisoning from bisulphide of carbon, and especially severe cases, were not infallibly much more frequent formerly than they are now. They have been reported in the rubber industry, the manufacture of artificial silk and extraction of gum, etc.

In 1910 the statistics of the Sickness Insurance Societies of Leipzig and neighbourhood furnished the following cases: among 2,226 rubber workers 1,041 cases of sickness occurred with 20 deaths, 63 affecting the nervous system and 52 being due to poisoning. The total morbidity percentage was 46.7 per cent. and total mortality 0.896 per cent., cases of morbidity from nervous diseases 2.83 per cent., and from poisoning 1.40 per cent.

Of 8 cases reported by Briaux in 1912, 2 showed no signs of insanity, 1 of loss of control over the sphincters, 1 of mental hebetude, 3 paralysis of the legs, and 4 effect on the genital organs.

In 1914 Kober reported two acute cases in Ohio.

Terrien in 1920 published two cases of marked amblyopia in workmen employed in a large factory for making mustard plasters. They had been engaged for eight hours a day in spreading on to special papers a solution containing 2 kilos of rubber dissolved in 1 litre of essence of mustard flour.

Dubois de Lavigerie reported two cases of poisoning affecting men employed in making invisible patches for shoes, affixing them by means of a mixture of rubber and gutta-percha dissolved in bisulphide.

Dieluafy noted several cases of poisoning in perfume factories in which the bisulphide was used to extract the essences from flowers.

An enquiry by Dr. Vandermieren (Brussels) in 1920 covered workmen in a factory for making toy balloons who were using bisulphide for vulcanising purposes. The occupation of the 40 persons thus examined was distributed as follows: 11 mounters, 9 dippers, and 20 blowers. Of the 9 dippers 7 showed no symptom; one, a beginner, had suffered from obvious symptoms and another from serious signs (paralysis of the legs). At the time of the visit a dipper showed nervous involvement mainly (violent headache, muscular cramps, paralysis of the legs, vertigo, etc.): another, digestive and nervous symptoms; a third similarly characteristic though less pronounced symptoms, and a fourth paralytic, cramps and muscular weakness.

Among the eleven female mounters, fairly advanced in age, only two cases of paresia of the limbs were observed; digestive troubles (anorexia, vomiting, etc.) were more common. Six cases of violent headache and diminished visual acuity were found in five women mounters.

Sixteen of the twenty blowers stated that previously they had suffered from symptoms of bisulphide poisoning.

Mattei and Sedan reported two cases, one in 1921 and the other in 1922, in a factory for extracting the grease from rags. They described another case affecting a young woman, an engineering chemist in a large oil works in Marseilles, engaged in titrating samples of fatty substances and oil cake with carbon bisulphide.

In the course of preparation of solid carbon bisulphide in a beaker (in which it had been prepared with the necessary precautions), by making the product fall by drop into liquid air, a chemist in the Institute of Inorganic Chemistry of Hanover met with a severe accident (1926). Care, therefore, should be taken to avoid mixing inflammable organic substances with liquid air. They should be kept separate during cooling by means of a screen.

In 1924 three cases were reported in Great Britain, two in rubber factories and one (severe) in the manufacture of artificial silk. In 1925 three cases were reported, in 1926 one case and in 1928 one case.

SYMPTOMS

The poisoning shows itself in two forms: acute and chronic. The acute form is of short duration and gives way rapidly, even fulminating, manner. This is bisulphide inebriation described by Delpech and now very rare in factories. It is only likely to be observed when a vessel breaks. It resembles alcoholic intoxication, followed by a narcosis recalling that of chloroform. The consequences, however, are more lasting and severer: pallor of the face, flaccid arms and legs, sometimes even complete insensibility, diarrhoea, coma, subnormal temperature, and death at the end of twenty-four to forty-eight hours. Dilatation of the pupil is of bad prognosis.

In the ordinary acute form, the two most frequent signs were headache and sleepiness during, and immediately after, work, and to them Glorieux and Gilbert attach great importance. This form is of short duration and gives way rapidly to nocturnal insomnia, which is very persistent and attended by nightmare. The headache, generally the first sign to show itself, often only a few hours, days or weeks after commencement of work, comes on usually in the evening and disappears at night, only to reappear on commencing work. This symptom, which sometimes assumes the deceptive form of the classical neuralgia of the trigeminal nerve, disappears entirely on continuance at work. An equally important sign is genital hyperaesthesia, the appearance of which may lead workers to change their employment. Glorieux deems the first sign to be great muscular fatigue, most often localised in the
lower limbs, general weakness, and exhaustion. Slight psychical changes occur (hilarity, loquacity, agitation, irritability, etc.); sometimes hallucinations of sight and hearing.

Vertigo and sometimes even syncope occur, inco-ordination, automatic-like movements, definite titubation, the appearance of being drunk, etc. Peripheral neuritis follows, generally affecting the muscles of movement; sensory affections (pins and needles feeling, anaesthesia), cramp-like pains, and sometimes troubles of sensation (hearing is more often affected than sight).

Naturally, in the majority of cases, gastro-intestinal and circulatory affections accompany the more characteristic signs; cough, oppression, and discomfort.

The general condition may become serious; coma may appear imminent, but a fatal issue is rare. Sometimes the toxic symptoms are very slight, consisting only of headaches, vertigo, marked mental hebetude, general malaise with slowing of respiration. These signs are transient and disappear quickly on the patient going into the outside air.

Chronic poisoning is seen especially after prolonged inhalation of bisulphide fumes. Generally the acute form constitutes the initial period of poisoning from carbon bisulphide, of which the second is the chronic form. This may set in without any obvious distinctive episode after several weeks, months, or years of work, subject to surrounding conditions and individual susceptibility.

The headache and digestive trouble persist and become aggravated, the patient sometimes presents a blackish line on the gums (resembling the Burtonian line, but which disappears quickly), progressive emaciation, atrophy of the muscles, etc., circulatory and respiratory troubles, slight and without objective signs are never wanting, but generally a return to normal occurs on cessation of work in a few weeks or months according to individual susceptibility. Urinary affections are rare, whereas those affecting the genital organs are well recognised (but are much less frequent now owing to the smaller quantities of the poison inhaled).

In women the menses are excessive, whereas those affecting the genital organs are well recognised, especially their appearance after the general signs of industrial poisoning by bisulphide of carbon. The lower limbs are generally attacked first, with weakness, stiffness, heaviness of the limbs and tremor, locomotor inco-ordination, with strange, staggering uncertain gait, etc.

In an early stage the patient suffers from a feeling of cold, numbness, pins and needles, then pain in the region of the nerve centres affected by the poison. Finally, hyperaesthesia or hypoaesthesia, or anaesthesia — one or the other. Tendon and skin reflexes of the lower limbs are generally abolished. The polyneuritis then generally extends to the legs, although sometimes it comes on as the first sign — especially in workmen who have continually dipped their fingers in the liquid.

The lesion commences with deranged sensibility (slight anaesthesia of the hands from which recovery is rapid), but if contact lasts too long some degree of loss of sensibility remains (disappearance of the feeling of relief to touch) or anaesthesia of the hand and forearm (supplied by the ulnar nerve especially) may remain. Balthazard has described, further, loss of sensation localised in the pectoralis major. The fingers become stiff, movements less precise, the entire grasp of the hand and forearm attacked weakens. Paralysis predominates often in the group of muscles comprising the flexor of the hand and fingers and interossei, with diminution or abolition or even exagge-
rational of the tendon reflexes. The paraplegic form may be associated with psychical disturbance, and it may be difficult to distinguish the part played by alcohol when this is also present.

Oliver frequently found peripheral neuritis in rubber workers appearing, in several cases, weeks after the worker had left the factory. On the other hand, workpeople can continue their employment for three or four years without being attacked by paralysis. Loss of use of the limbs is often preceded by muscular inco-ordination. There is staggering gait. The vapour frequently causes drowsiness. During foggy weather the symptoms become worse. So far as relates to nervous affections in women, Oliver noted twice the following effects: vertigo, headache, lassitude, loss of appetite, and taste of the vapour in the mouth; in others the symptoms resembled those of drunkenness. After the day's work, women staggered home and before even touching their food they fell into a deep sleep. The following morning they complained of headache, felt nervous and tremulous, and only recovered themselves after an hour or two in the factory. Oliver found some workers intoxicated to such a degree as to be maniacal and threaten suicide.

Affections of the central nervous system are equally important. Some authorities have diagnosed (though rarely) the condition of poliomyelitis as due to bisulphide, and this has also been produced experimentally in animals. The intellect is first excited and then depressed — the most obvious and first observed condition. No joy in work, sadness, indifference, lack of courage, melancholia, fairly frequent sleepiness, mental dullness, loss of memory. Later there is tendency to hebetude, suicide, mania, of which bisulphide inebriation is a paroxysmal exaggeration with staggering gait, impulsive acts, often of a serious nature, and a change, more or less pronounced, in the system in general.

According to Laudenheimer, who collected the clinical histories of 50 cases of bisulphide madness, this comes on in the first weeks or months of exposure to the poison, very much more rapidly than the paralyses. There is frontal headache, vertigo, dull lassitude, transitory periods of excitement, slight delirium; then comes on profound depression, apathy, melancholia, and loss of memory. The somnolence sometimes takes the form of acute mania or melancholia, with persecution delirium. A cure takes place unless the affection is so severe as to become permanent.

Exactly how bisulphide acts in giving rise to the acute mania, and the different delirious conceptions, etc., is doubtful.

Marandon de Montyel is of opinion that only organic or primitive dementias, that is to say unprecedented by mental disease, ought to be attributed to the exclusive action of carbon bisulphide. According to him, furthermore, it is the patient's constitution and not the poisonous dose which determines the mental form of the psychopathy. The other affections (delirium and various forms of insanity) are due, similarly, not to the poison, but to the psychopathic predisposition of the workpeople who handle it.

**Ocular symptoms.** — Diminution of visual acuity is a very important early symptom. In a certain number of cases, however, the amblyopia develops early in the poisoning and progresses without pain, very much like tobacco amblyopia. Hence at fixation causes photophobia and watering of the eyes. The amblyopia is due to inflammation of the optic nerve, and is complete in three months' time if the patient continues at his work. If the attack has been severe, recovery of full vision is practically impossible. The trouble of fixation, the photophobia, the diminution in sight, and the watering of the eyes are obstacles to appreciation of changes in the visual field which, however, is found to be contracted. There is a central scotoma, for red, a rather inconstant feature, but which, if present, has great diagnostic value (Terrien). Dyschromatopsy and nyctalopy, sometimes xanthopsy (the most frequent), as well as choropsy and erythrospy, are almost constant. The prickling sensation in the eyes complained of by the workers disappears as soon as work ceases, and the patient gets into the fresh air; the amount of lachrymation is small without conjunctival hyperaemia. Some writers speak of an anaesthesia of the cornea which others have not found. The eye reflexes are normal. Lehmann has described sluggishness of the pupil and inequality in size. One single case (Litten) of total double ophthalmoplegia and of divergent bilateral strabismus (Golesciano 1907) has been described.

**Course.** — The slight cases of acute poisoning recover rapidly on withdrawal from the poison, and prognosis is favourable provided there is cessation from dangerous work.

So far as chronic poisoning is concerned prognosis is favourable in the matter of life, but bad in that of health.
never becomes a man again" (Delpech). The chronic phase progresses slowly and the general inclination is distinctly downhill; it is interrupted from time to time by acute relapses, which point to a period of excitement and are due to absorption of a larger dose than usual. After treatment, more or less long, the patient recovers his health, but relapses are usually more severe than the previous attack. The course rarely ends in death unless it be by cachexia.

The polyneuritic lesions get better as the poison is eliminated and no further exposure takes place.

The mental affections also get better easily; but the most severe forms are those in which there is a hereditary predisposition. Such are those with irreparable damage, such as eye changes, which come on with great rapidity, and once set up, are only with difficulty and very rarely cured. Hearing is re-established with difficulty as well as memory for words.

**Diagnosis**

Except the bisulphide inebriation, no specific symptom serves to stamp the nature of the poisoning; and in the case of that, as of all other effects of carbon bisulphide, absence of the history and of a complete clinical examination makes the diagnosis very uncertain.

Diagnosis depends on knowledge of the workman's occupation and of the conditions of his work; the suddenness, too, with which generally symptoms appear. Among the more important signs are headache, and diminution of visual acuity, the smell of the breath, and emanations of the patient, vertigo, digestive troubles, and excitability. The later depressive symptoms are less characteristic.

Differential diagnosis in the acute condition has to be made from poisoning due to aniline, petrol, benzene, sulphur chloride, carbon tetrachloride, sulphuretted hydrogen, carbon monoxide, illuminating gas, chloroform, ether, food poisoning, acute alcoholism, and psychic troubles, hysteria. It is made the more delicate as mixed effects may be present as, e.g. in rubber workers in whom the bisulphide poisoning is often complicated by the effects due to benzene, sulphur chloride, and carbon tetrachloride.

In chronic poisoning differential diagnosis has to be made from poisoning by lead, mercury, arsenic, various causes of paresia, such as locomotor ataxy, progressive muscular atrophy, hysteria, neurasthenia, chronic alcoholism with kidney disease, and failure of the mental powers with muscular weakness and loss of movement.

**Demonstration**

(a) In the air.—Qualitatively carbon bisulphide is readily recognised by the very peculiar odour (heavy and sweetish, resembling that of chloroform); quantitatively Lehmann recommends Gastine's method: pass finely-divided air into a saturated solution of 20 per cent. caustic potash in alcohol at 96° C. The bisulphide of carbon is fixed as potassium xanthogenate. The vessel in which it has been absorbed is emptied, it is rinsed with a mixture of water and alcohol in equal parts, and is acidified with weak acetic acid. Neutralisation is effected by adding an excess of carbonate of lime. A solution of starch is added and equal parts of water and an alcoholic solution of potash. Titration is then made with a solution of iodine containing 1.667 mg. per litre, until a faint blue tint appears. One cubic centimetre of the solution is equivalent to a milligram of carbon bisulphide. Lehmann has obtained good results with this method, and Laudenheimer has found by its means in well-ventilated rubber vulcanising factories 0.2 to 0.3 mg. of carbon bisulphide per litre, and in badly-ventilated 1 to 2.4 mg. Kohn-Abrest gives a variation of the method. After acidifying with weak acetic acid, a 1 in 20 solution of copper sulphate is added, when a yellowish-golden precipitate is obtained. In adding this solution carefully the moment is noted when, as a result of an excess of the copper salt, the liquid lying above the yellow-gold precipitate begins to get coloured.

The dosage is still done by utilising the reaction with sulphate of copper (Kohn-Abrest). The copper xanthate readily falls down, and the end of the precipitation is recognised without difficulty. An excess of alkali must be avoided. The carbon bisulphide is converted into xanthate, then saturated with cream of tartar or bicarbonate of soda. The 1 in 20 copper sulphate is added slowly. This last reaction has been used to determine the amount of carbon bisulphide in illuminating gas.

Ethereal solution of triethyl phosphine with an equal quantity of ethereal solution of carbon bisulphide gives a crimson crystalline precipitate.

(b) In the body (post mortem) carbon bisulphide has never been detected. The urine gives off a characteristic radish-like smell due to a derivative of carbon bisulphide. When heated gently with Fehling's solution the urine gives a special kind of precipitate; a brownish black colour (Gaul is noticed due to the presence.
ence of haematin coming from the destruction of the red blood cells.

HYGIENE

The manufacture, handling, and use of carbon bisulphide should be carried out as far as possible in airtight closed automatic apparatus.

Ventilation of the workrooms should be well planned. Fume removal should be effected by downward exhaust ventilation at floor level. Workers should stand on platforms and not work in pits or in a bent attitude. In general ventilation should possess two principal characteristics, i.e. should be powerful and should be applied as near as possible to the point of origin of the fumes.

These are the measures now generally employed, and they explain the relatively small number of cases of poisoning found, despite a much greater consumption of the substance than ever before.

Substitutes for carbon bisulphide with less toxic properties should be adopted whenever practicable, as, for example, carbon tetrachloride, trichlorethylene, dichloromethane, acetone, etc., according to the precise process in question.

Waterproof clothes, gloves, and footwear are necessary, but it should not be forgotten that clothes, walls, floors, etc., readily become impregnated and require to be frequently and thoroughly cleaned. Alternation of employment with rest periods or work in shifts should be arranged.

Personal hygiene resolves itself into abstention from excess in alcohol and tobacco. Milk should be taken. Monthly medical examination is called for, with an initial examination before employment so as to eliminate subjects likely to become affected and those with organic defects. Every workman showing susceptibility (tremor of the hands, weakness of the legs, visual defects) ought to be transferred to other work or rejected altogether. Susceptibility may manifest itself afresh even after prolonged treatment as soon as fresh exposure takes place.

Workers should be informed of the dangers incurred.

To prevent risk of explosion and fire the bisulphide should be delivered in drums and unloaded, guarding against violent shock. The drums should be discharged close to the place where they are to be emptied and in summer placed in the shade and watered so as to keep down the pressure inside, arising from the tension of the vapour. In industries using the substance emptying can best be done under water, as the difference in specific gravity between the two keeps them separate, and it might well be distributed by means of compressed air in pipes kept under water. Smoking must be prohibited. The motive power requires to be in a separate building quite isolated from the workrooms. Lighting should be by electric light in airtight globes. Gearing and fuses should be outside the building in closed boxes. Heating should be by hot water pipes as the bisulphide takes fire on steam pipes.

Fire extinguishers should be ready to hand.

LEGISLATION

Employment of women is prohibited in the manufacture of carbon bisulphide in Argentina; in stores and workrooms in which acid vapours are given off in France; employment of young persons of less than sixteen years and female young persons of less than twenty-one years of age in the manufacture in Belgium and Spain; in the use of bisulphide in the extraction of oils, soaps, bleaching, in varnishes made with rubber, etc., in Spain; young persons under sixteen years of age and female young persons under eighteen years in the manufacture in Greece; young persons of less than eighteen years in stores and in the manufacture and use when large quantities are in question and in workrooms in which dangerous gases are given off in France; in the cold vulcanisation process in Germany and Switzerland; young persons of less than fifteen years of age and women of less than twenty-one in the manufacture in Italy, etc. The Netherlands law only deals with work in premises where toxic vapours are given off to such an amount as to be considered dangerous to health by the inspector of factories. The Regulations of February 1895 deals with the employment of women and children in industries using carbon bisulphide.

In Belgium the Royal Decree of 23 February 1895 deals with the employment of women and children in industries using carbon bisulphide.

The Regulations of 5 February 1896 of the Permanent Committee of the Provincial Council of Brabant prescribes as further Regulations:

(1) Installation of a suction hood connected up with a fan opposite each receptacle. The hood should have a length equal to that of the vessel and a height of at least ten centimetres.

(2) The tables on to which the dipped articles are placed should be perforated and the perforations connected up with the same fan. The
same should apply in the case of tables on which the boards are placed for receiving the articles dipped in carbon bisulphide.

(3) A linear velocity shall be kept up in the hoods referred to in paragraph (1), and the openings in paragraph (2), of at least 20 cm. per second, that is to say, appreciable by the special Bürani anemometer used by the inspectors of factories.

In France the Decree of 10 May 1904 places obligations on the employer of taking measures to prevent poisoning by carbon bisulphide. The circular of 20 January 1909 relates to the manufacture of rubber.

In Germany the Order of 1 March 1902 (Reichsgesetzblatt, page 59) relates to the installation and working of industrial establishments engaged in the vulcanisation of rubber articles.

The principal requirements relate to the flooring (at the same level as the ground level), the opening (or windows in a must be made to open) capable of supplying sufficient air renewal, to mechanical ventilation, to the arrangements for preventing escape of vapour. Vulcanising workrooms must not be used as living rooms, for the preparation of food, warehouses, or drying purposes but only for vulcanisation. Remaining in rooms except as necessitated by operations connected with vulcanisation is prohibited. Cubic space must be 20 meters per person. Only such quantity of bisulphide as is necessary for the vulcanising processes going on shall be brought into the workrooms. Reception rooms must be airtight. Vulcanising and drying rooms must be heated by hot water pipes or steam. Artificial lighting by electricity is required to be installed under certain conditions. Vulcanising machines must be provided with hoods connected up to extraction fans, so that the air shall not contain more than \( \frac{1}{3} \) to 1 per 1,000 of vapour. Vulcanising must be carried on under hoods where the workman shall introduce only his hands and such as to prevent the vapour from reaching the face. Drying shall be done in special rooms or under aspirating hoods. Drying rooms shall be so constructed that it shall not be necessary for the workpeople to enter for the introduction or removal of the articles.

Not more than two hours’ continuous work at the most and not more than four hours in the day, with an interval of at least an hour, shall be allowed. The employer shall supply overalls. Washing and cloakroom accommodation (for both sexes) shall be provided, maintained in a clean condition and shall be capable of being heated in cold weather; provision of soap, towels, etc., and cupboards for keeping the clothing, monthly medical examination by a surgeon approved by the inspector of factories, with power to suspend from work workers showing symptoms of poisoning, shall be compulsory.

A Ministerial Circular (Prussia), dated 23 February 1910, deals with the manufacture, storage, and use of carbon bisulphide. German regulations prescribe that in the case of installation of inflammable liquids the piping must be underground.

In Great Britain the India-rubber Regulations of 31 March 1922 under section 77 of the Factory and Workshop Act, 1901, relate to processes in the manufacture of India-rubber, or of articles or goods made wholly or partly of India-rubber.

The regulations define “fume process” and “lead process”.

“Fume process” means any process in which use is made of carbon bisulphide, chloride of sulphur, benzene, carbon tetra-chloride, trichlorethylene, or any carbon chloride compound or from which the vapour of any of these substances is given off.

The Regulations prohibit employment of any person of less than 18 years of age in a fume process, and of any person less than 16 in any room in which a fume process is carried on, unless a standard ventilation of 30 changes of air per hour is maintained.

No person shall be employed in a room in which carbon bisulphide is used for more than five hours in all in any one day nor for more than 2½ hours at a time without a rest interval of at least one hour from any employment.

A fume process shall not be carried on in the open air or in any room the floor of which is in any part below the level of the surrounding ground. A fume process shall not be carried on without an efficient exhaust draught so contrived as to operate on the vapour given off as near to the point of origin as possible, except when the standard ventilation of the room provides for 30 changes of air per hour.

In the vulcanising of waterproof cloth the machine shall be so arranged that the mechanical feeding-in and delivery of the cloth takes place outside the enclosure. Further, the trough containing the vulcanising material shall be fed only by natural flow from the reservoir containing the solution. The reservoir itself shall be enclosed. Periodic medical examination shall be made by an appointed surgeon. General welfare arrangements are also enjoined.

Both in Belgium and Great Britain the periodic examination is required every month.

Poisoning by carbon bisulphide is statutorily notifiable in Great Britain, Bavaria, Western Australia, Pennsylvania, and the Netherlands. It is scheduled as a disease for which compensation can be obtained under the Workmen’s Compensation Acts in Germany, Great Britain, New Brunswick, Bolivia, Finland, Italy, Queensland, Western Australia, and in the United States (Minnesota, New York, Ohio), Porto-Rico, in Argentina, Brazil, Chile, and Switzerland.
CARBON MONOXIDE

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Prof. Balthazard

Carbon Monoxide

French: Oxyde de carbone.—German: Kohlenoxyd.—Italian: Ossido di carbonio.—Spanish: Oxido de carbono.

CHEMISTRY

Symbol: CO. Colourless, inodorous gas, not irritating, tasteless, containing 57.13% of oxygen and 42.87% of carbon. Slightly soluble in water, which dissolves only 25 c.c. per litre at 15° C.; liquefies at —141° C. under a pressure of 36 atm.; solidifies at —211° C. Specific gravity (in reference to air): 0.967. Limit of explosibility of a mixture of air with carbon monoxide (in contact with a flame): 16-17 per cent. of carbon monoxide.

Carbon monoxide results from incomplete combustion of carbon due to an insufficiency of air or oxygen. Combustible itself it burns with a blue characteristic flame becoming converted into carbon dioxide. It reduces a solution of palladium chloride precipitating black metallic palladium (not very characteristic), ammoniacal nitrate of silver (reaction increased by heat; not characteristic); liberates iodine from a hot solution of iodine pentoxide; is absorbed by cuprous chloride in ammoniacal solution and gives CuCl₂, CO₂H, O water of crystallisation; forms a very stable compound with haemoglobin which has been thus obtained in a crystalline state.

SOURCES OF POISONING

The sources of poisoning are very numerous; frequently the intoxication is the result of what has the character of a single accident or of repeated accidental exposures. When it is a question of heating and lighting by solid, liquid or gaseous fuel, the production of carbon monoxide is inevitable.

The most important sources of poisoning are:

(a) Coal gas (see "Gas works"), which contains up to 12 per cent. of carbon monoxide. If the gas is carburetted with water gas the percentage of carbon monoxide can reach 27 or even 29. Danger occurs from leaky pipes, accidental opening of taps, faulty installation of gas stoves etc., and wherever gas or gas fires without flues replace hearths (see under f), principally in the heating of small melting pots (e.g. in soldering, and in casting monotype and linotype characters). Gas works labourers, plumbers employed underground in installing or repairing gas mains, mechanics in charge of gas engines, and persons engaged in inflating balloons are specially exposed to risk. The toxic effect of other constituents of gas should not be forgotten: e.g. benzene (0.5 to 1 per cent. in gas) and the light oils (up to 5 per cent.).

(b) Industrial gases. Gaseous mixtures, such as water gas, blast furnace gas, power gas (Dowson, Mond, etc. — see "Industrial Gases") are very dangerous in view of their high content in carbon monoxide, which varies from 25 to 40 per cent.

(c) Iron and steel works. Blast furnaces. (See article "Iron, Pig Iron and Steel Industries".) The reduction of the ore evolves carbon monoxide \( \text{Fe}_2\text{O}_3 + 3\text{C} = 2\text{Fe} + 3\text{CO} \), and the gases which escape from blast furnaces contain a considerable amount (up to 30 per cent.). The danger is present during charging by hand (old style), tapping the metal or slag, and in puddling. Exposed to risk also are the cleaners and repairers of furnaces and flues, workmen attending to regenerating furnaces, especially when built below ground (old installations), etc.

(d) Coke ovens and wood charcoal. Carbon monoxide is given off in quantity, especially when the ignited coke is extinguished by water. The gases given off by the slag heaps of blast furnaces are also rich in carbon monoxide.

(e) Metallurgical and engineering industries. (See article "Mechanical Engineering".)

(f) Foundries (metallurgy of iron, zinc, mercury, silver, lead, etc.) where carbon monoxide is given off from
the furnace hearths of melting pots; dipping baths, vats, lime kilns, etc. Persons employed in the upper part of the shop (crane minders for charging the furnaces, glaziers, etc.) may be affected by the ascending gas, as also may tinsmiths soldering in badly ventilated places and using soldering pots heated by charcoal, workmen attending to the dryers in brass and iron foundries, etc. Cases have also been reported in blow-pipe welding from the small quantity of carbon monoxide in the compressed hydrogen (made with water instead of hydrogen obtained from compressed hydrogen (made with water quantity ed in blow-pipe welding from the small dried, etc. to the driers in brass and iron foundries, etc.). Heated by charcoal, workmen attending the smiths soldering in badly ventilated places and using soldering pots may thus be affected by the ascending gas, as also the crane minders for charging the shop (crane minders for charging the shop). Persons employed in the upper part of furnaces; in manufacture of celluloid and other synthetic substances (e.g., acetone, oxalic and sulphuric acid); in the dissection of animals, in the wool works, in the production of nitroglycerine, in the production of nitrocellulose, in the preparation of carbon monoxide, whether by the oxalic and sulphuric acid method or by that of sulphuric acid and ferroanide of potassium. In toxico-

Carbon monoxide

(l) Smoke containing a percentage of carbon monoxide which is higher than the normal gives danger during fires (see article "Firemen"), especially when the fire has not made its way to the open (also in tunnels), to man on passage ways and looking after the trolley lines, to chimney masons, chimney sweeps, cookers, etc. Smoke from mineral oil lamps or tobacco or stoves, etc., in badly ventilated premises is also dangerous.

(m) Dust containing carbon monoxide affects chauffeurs, cleaners of boilers and pipes of generators in the most diverse industries; workmen in coke ovens (frequently) and paper mills, persons employed in the dry distillation of rags, or their treatment by quicklime.

(n) Textile industry: cloth singeing, gassing rooms, etc.

(o) Exhaust gases from motors (petrol, benzene, etc.) containing a percentage of carbon monoxide of from 3 to 14 per cent. In 1922 an enquiry made at Pittsburg (U.S.A.), extending to more than 100 motor vehicles of the most varied description, brought out that the proportion of carbon monoxide in the exhaust gases was 0.5 to 14 per cent. Hence the danger to mechanics working in closed garages near a motor car kept running, especially at the exhaust outlet; and to chauffeurs who drive from the inside of closed cars because of the passage of exhaust gases to the inside in the absence of good ventilation. (Account must also be taken of the role played by the products of overheating of the lubricating oil.)

(p) Use of carbon monoxide on ships for destroying rats (apparatus proposed by Nocht and Giemsa). The persons engaged in disinfection as well as the sailors who enter the cabins, etc., after insufficient ventilation, run risk.

(q) Hearths with badly acting exhaust: owing to defective installation or accidental causes: obstruction in the pipes, ill-fitting doors or premature closing of the doors or of the dampers; cracks, faulty construction, defects in the draught owing to weather conditions (affecting cooks, watchmen, bakers, furnacemen, etc.).

(r) Scientific processes in laboratories, especially chemical, during the preparation of carbon monoxide, whether by the oxalic and sulphuric acid method or by that of sulphuric acid and ferroanide of potassium. In toxico-
logical laboratories in the course of experiments on the physiological effects of carbon monoxide.

TOXICOLOGY

Absorption. — Traces of carbon monoxide given off habitually in combustion may be considerably increased by a variety of causes affecting the draught, such as atmospheric pressure, wind, temperature, humidity of the air, etc. Further, the kind of fuel, and the way in which the fire acts, are important factors which should not be forgotten.

On the other hand, individual susceptibility varies with the general constitution of each person, the precise state of the organs, etc., as for example the respiratory capacity (deep respiration of the organs, etc., as for example the transformation of each person, the precise state of consciousness, with 0.4-0.5 per cent. and death, or at least loss of consciousness, with 0.4-0.5 per cent. (Case described by Deal.) The air would be highly dangerous at the end of an hour if 2 mg. per litre were present, and death would appear to ensue at the end of 20-30 minutes in presence of 4-5 mg. of carbon monoxide per litre; rapidly with 10 mg. per litre. Haldane considers that even 0.05 per cent. can cause symptoms.

A man at rest can breath an atmosphere containing 1 mg. of carbon monoxide per litre for two hours and a half before 50 per cent. of his blood is saturated, but if he engages in active work symptoms would show in less than an hour.

The Mines Department of the United States regards 0.18 mg. per litre as a dangerous limit, and as fatal, 0.48 mg. In cases of continuous exposure even a quantity of 0.06 mg. is looked upon as dangerous, in view of the cumulative action of carbon monoxide. In fire damp mines the Department fixes as the limit of safety a dose of 0.024 mg. in presence of good ventilation. Haldane in 1906 decided that the maximum to be permitted in the London tubes was 1/10,000, and Henderson of the New York Tunnels Committee is of the opinion that 4/10,000 can be tolerated without bad effects during three quarters of an hour.

The respiratory tract is the most important practical channel of absorption. Carbon monoxide is absorbed through the lungs into the blood and the transformation of the oxyhaemoglobin (HbO) of the red cells into carboxyhaemoglobin (HbCO) commences in the capillaries of the alveoli and depends on the rapidity with which the carbon monoxide passes into the blood vessels.

According to most toxicologists carbon monoxide can already be fixed by the haemoglobin if only minute traces are present (1 in 15,000) and is only displaced by oxygen slowly, depending

remembering the particular susceptibility of each individual and especially the condition in which the subject finds himself at the moment of poisoning (see above).

So far as the minimal dose is concerned no person would be affected if he breathed, even for an hour, air containing less than 0.30 mg. per litre of carbon monoxide (Mosso). The first symptoms would appear to come on at the end of an hour with a dose of 0.35-0.40 mg. per litre. Persons, however, who with great courage have submitted themselves to experiment have shown very serious symptoms in 30 minutes with a mixture containing 0.43 per cent. and death, or at least loss of consciousness, with 0.4-0.5 per cent. (Case described by Deal.) The air would be highly dangerous at the end of an hour if 2 mg. per litre were present, and death would appear to ensue at the end of 20-30 minutes in presence of 4-5 mg. of carbon monoxide per litre; rapidly with 10 mg. per litre. Haldane considers that even 0.05 per cent. can cause symptoms.

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According to most toxicologists carbon monoxide can already be fixed by the haemoglobin if only minute traces are present (1 in 15,000) and is only displaced by oxygen slowly, depending
on a number of physiological factors and taking at least several hours.

Carbon monoxide is not a poison of living protoplasm, but it acts by suppress the property that haemoglobin, whether globular or muscular, has of fixing the oxygen at the level of the lungs and of carrying it to the tissues.

The quantity of carbon monoxide fixed by muscular haemoglobin is slightly less than that fixed by globular haemoglobin. The affinity of carbon monoxide for haemoglobin is very great; it is estimated to be 210 times as great as that of oxygen for haemoglobin. It forms with this a relatively stable compound, even when it is brought constantly by the circulation into contact alternately with carbon dioxide and oxygen. According to Gréhant, at any rate not in any large number of physiological factors.

Carbon monoxide, therefore, is not a poison, since the combination which it forms with haemoglobin is fairly easily dissociated; it acts rather in the manner of an inert gas by diminishing the quantity of oxygen placed at the disposal of the tissues, thus producing anoxaemia. According to the personal experience of Haldane, this only commences to take effect (with cerebral symptoms) when about a third of the

toxic action on the organism. Those holding the first view, which tends to stress as of capital importance the mechanism of asphyxia, maintain (as explaining all the symptoms produced by carbon monoxide in the organism) that, at the moment of death in acute intoxication, the anoxaemia reaches the same degree as is the case in asphyxia; and that in artificially supplying oxygen to the tissues carbon monoxide cannot have a fatal result.

Importance is attached to the usefulness of determining what Balthazard and Nicloux have called the "coefficient of intoxication", i.e. the ratio of the quantity of haemoglobin rendered unusable, as a consequence of its combination with carbon monoxide, to the total quantity of haemoglobin for a particular volume of blood. This value is estimated between 0 and 1 and gives the exact measure of anoxaemia; multiplied by 100 it expresses the percentage of haemoglobin thrown out of action for the normal functions of the blood. Death supervenes when two thirds of the haemoglobin have become unfit to perform the function in question.

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1 In spite of the improvements proposed by Nicloux, this method is a delicate one and takes at least two hours.

Balthazard has just proposed (1924) a method of spectroscopic determination of the coefficient which takes less than a minute and requires only a drop of blood. It is based on the different position in the spectrum of the bands of oxyhaemoglobin and carboxyhaemoglobin. Considering only the left band, one determines with the spectroscope (spectroscope of Yvon) that the maximum intensity for oxyhaemoglobin corresponds to the wave-length 577, and for carboxyhaemoglobin to the wave-length 570. Mixtures of oxyhaemoglobin and carboxyhaemoglobin give a left band of which the maximum intensity corresponds to a wave-length intermediate between 577 and 570, and tending the more to approach the last value as the blood is the more rich in carboxyhaemoglobin.

It is sufficient, then, to dilute in a little boiled water a drop of blood from the body, to examine this spectroscopically and determine the wave-length of maximum intensity of the left band, which determination is facilitated by a ruled eye piece micrometer between the lines of which the band is circumscribed symmetrically in relation to the brightest part. A simple reading of the table standardised before by means of titrated mixtures enables one to know the coefficient of poisoning, examined. The error does not exceed 5 per cent.
haemoglobin is changed into carboxyhaemoglobin (about 8 c.c. of carbon monoxide to 100 c.c. of blood) no matter what amount of carbon monoxide there is in the air breathed. Serious symptoms show themselves when half the haemoglobin is saturated (12 c.c. per 100 of blood).

In practice the quantity of carbon monoxide contained in a known volume of blood is determined and one investigates the maximum quantity of carbon monoxide that this same volume of blood is capable of fixing; the quotient of the two values is then obtained.

The coefficients of intoxication in different persons are extremely variable because of a number of factors of which several readily escape us. But it is especially low in aged persons, little resistant to anaemia, and those who have been venereal lesions; it is increased, if the intoxication has occurred rapidly, in an atmosphere rich in carbon monoxide; and can be lowered if the duration of intoxication has taken several hours and in an atmosphere not very rich in carbon monoxide.

**Blood.** — Experimentally and clinically diminution in the oxygen and carbon dioxide contents of the blood has been found. The diminution in the latter would seem to be bound up with a diminution in the alkalinity of the blood; without any doubt the diminution of carbon dioxide is the cause of the lessened alkalinity of the blood (due also to default of oxygen).

There is an increase of sarcoldatic and other acids (especially sulphuric and phosphoric) derived from the destruction of albumin exaggerated by the carbon monoxide intoxication. Clinical examination of the blood as effected by various authorities has given rise to very contradictory results. If the haemoglobin is generally diminished, even with an increase in the red blood cells (up to 11,200,000), this is not the view of other authorities who have even reported a diminution of the number. The shape of the red blood cells is not affected. Sometimes red blood cells are found in which the reticulo-filamentous substance is of a bluish colour and the granular substance reddish violet; sometimes there are none of these young or immature forms; sometimes nothing special is observed about the platelets and sometimes notable increase of them, slight leucocytosis with increase of neutrophils and no cesinophilia, which according to some is said to be of serious import in prognosis; coagulability of the blood during life is increased.

**Elimination.** — If the affected person is withdrawn from the toxic atmosphere the carboxyhaemoglobin is broken up, and after a variable time the haemoglobin ceases to contain any carbon monoxide. Neither the degree nor the duration of the poisoning or the manner in which it occurred have any constant relation with the elimination of carbon monoxide — a thing dependent on the rapidity of intervention. Whether this takes the form of supplying fresh air or especially pure oxygen for inhalation, it has been proved that at first the affected blood readily gives up the poisonous gas. But later this yielding becomes more difficult, the chemical combination probably becoming gradually more stable.

Hence the importance of early intervention of prolonged artificial respiration and especially inhalation of a mixture of oxygen and carbon dioxide (8-10 per cent.) — a mixture which induces deeper breathing and favours elimination of carbon monoxide at a rate 5 to 6 times as rapid as would normal air, even when 30-40 per cent. of the haemoglobin is in combination with carbon monoxide.

**Statistics**

Many writers maintain that the majority of cases of carbon monoxide poisoning remain unknown and that only the serious ones appear in statistics. The Health Office of the German Empire considers that no data as to conditions in industry could state with certainty what the occupational risk from carbon monoxide was. German statistics on the occupations most liable to this form of poisoning (firemen, gas workers, miners, etc., excluding the victims of explosion) do not show high figures. In the United States, of 112,987 iron and steel workers in the Illinois Steel Company during five years (1916-1920) 271 (with 13 deaths) were reported as poisoned by carbon monoxide.

In Great Britain the reported cases, i.e. cases in which incapacity lasted one whole day, were:

<table>
<thead>
<tr>
<th>Kind of gas</th>
<th>1913-14</th>
<th>1915-19</th>
<th>1920-23</th>
<th>1924-26</th>
</tr>
</thead>
<tbody>
<tr>
<td>Producer gas (water, lathe, mind, suction, etc.)</td>
<td>114 (12)</td>
<td>123 (12)</td>
<td>120 (8)</td>
<td></td>
</tr>
<tr>
<td>Blast furnace gas</td>
<td>112 (9)</td>
<td>97 (6)</td>
<td>93 (5)</td>
<td></td>
</tr>
<tr>
<td>Coal gas</td>
<td>36 (3)</td>
<td>64 (8)</td>
<td>140 (7)</td>
<td></td>
</tr>
<tr>
<td>Gases from other sources, e.g. coke ovens, lime kilns, braziers, etc.</td>
<td>77 (10)</td>
<td>64 (9)</td>
<td>132 (9)</td>
<td></td>
</tr>
</tbody>
</table>

| 359 (59) | 378 (44) | 385 (30) |

1. The fatal cases are given between brackets.

The mortality has been, therefore, 12.7 per cent. for the period 1908-1912, 16.4 per
 Poisoning can take three forms: massive, acute, and chronic.

(a) Massive intoxication. — Massive intoxication occurs by rapid inhalation of large amounts of carbon monoxide—at the moment of tapping blast furnaces, cleaning and repairing gas mains, especially when underground. It is characterised by almost instantaneous falling down, loss of consciousness and rapid death. In the event of survival there may be long continued nausea, vertigo, headache, convulsions, etc.

(b) Acute intoxication. — The premonitory symptoms often pass unnoticed and in the first stage the individual has violent frontal headache, feeling of constriction about the temples, nausea, sometimes vomiting, hallucinations of sight and hearing, dyspnœa accompanied by retro-sternal and precordial pain. At first the affected person may have retarded respiration, and then or later convulsions, Cheyne Stokes breathing, with weak and irregular pulse. A characteristic of the second stage before loss of consciousness—constantly preceded by tendency to sleep—is the diminution or abolition (especially in the lower limbs) of the power of movement, the intellectual faculties remaining intact. At times there is euphoria and even psychical excitement; at times sub-normal temperature followed by a rise (not necessarily associated with lung complications). The face at first pale becomes carmine red; the skin is lived, or shows pink patches. Loss of consciousness can pass into coma, but in some cases there may be motor excitement (tremor, clonic and tonic spasms, sometimes tetanic with opisthotonos and trismus) which have been known to appear even in the first stage.

If the second stage does not terminate in death it is followed by a third in which the dyspnœa becomes very marked, respiration superficial, irregular (Cheyne Stokes), stertorous, and the pulse feeble. The temperature falls, the face becomes cyanotic, the mucous membranes congested, the pupils dilated and the reflexes diminish or disappear. If intoxication has been pushed very far, the coma persists and death is delayed. In cases of recovery return to life takes place with retrogression of the symptoms, and after a variable length of time a cure is effected which, however, is not always complete.

Among the sequelæ the most frequent are motor troubles (paralysis, hemiplegia due to cerebral softening, myelitis, polyneuritis, etc.), or trophic (œdema, ecchymoses, bullæ, eschars, etc.), or psychical (frequent and severe: mental confusion, amnesia, which may last and go on at times to dementia, maniacal seizures, etc.), or simply neuropathic or cardio-pulmonary (pneumonia, congestion, œdema, haemoptysis), or digestive affections. Wasting is also reported or a general asthenia with intense anaæmia, albuminuria, glycosuria, etc. If the typical forms are as thus described not a few cases are atypical in a high degree by reason of the personal factor. Among these atypical forms of acute intoxication the "abortive" form should be remembered with its reduced clinical picture, due to an intoxication of short duration with rapid recovery, and rarely showing the presence of carbon monoxide in the blood; or a "relapsing" form in which the symptoms recur after some days or weeks, and lastly a "late" form in which the signs do not appear until after some time.

(c) Chronic poisoning. — The question of the existence or not of this form has been much discussed and is not yet settled. In any case one should be very cautious before assigning the signs observed to the action of carbon monoxide because the connection is often far from clear. On the other hand some authorities consider that the action of small doses of carbon monoxide cannot be without effect on the organism—not only on the blood and the blood forming tissues but also on metabolism. They consider that 80 per cent. of the cases of poisoning by carbon monoxide remain unrecognised because the sufferers complain of indefinite symptoms that remain incurable and cannot be diagnosed. Errors in clinical diagnosis of these affections would appear to be pretty easy, and cases of meningitis, typhoid fever, etc., have been ascribed to carbon monoxide.

Possibly former hygienic conditions have been so defective (ventilation, heating by open braziers, etc.) that poisoning showed itself with symptoms which to-day are only met with more or less rarely or under quite exceptional circumstances. In this way one can understand the cases described in cooks (by Moreau in 1869 and by
Sée in 1873, under the name of "madness of cooks"), in ironers, tailors, etc. Nowadays chronic cases are reported among persons employed in places where heating and lighting are defective or where heating and lighting are defective or the mains or pipes allow escape of gas.

A certain number of stigmata of this intoxication are described but at all events the symptoms vary very much from the simple headache (at times intolerable) to nausea, vertigo, neurasthenia, and marked loss of muscular power. Occasionally digestive troubles are mentioned (dyspepsia, nausea, vomiting, anorexia, etc.), circulatory affections (palpitation, oppression, angina pectoris), disturbances of sight (amblyopia, choroidal congestion, diplopia), nervous complaints (insomnia, sleep during the day, change in the character, anxiety, irritability, neurasthenia, amnesia), trophic, vaso-motor or vascular changes. But the most remarkable and most frequent symptom is said to be a degree, more or less variable it is true, of anaemia. In this connection one must remember that in the daily round of work such symptoms as have been enumerated above are not convincing.

Occasionally the analysis of the air of the place, because it can happen that the individual who has succumbed was found still alive when the atmosphere had ceased to be dangerous. Often it is very difficult if not impossible to visualise the conditions under which the accident has happened. Certain factors are not slow in disappearing, like the gas itself, and others escape altogether.

**DIAGNOSIS**

In those who have survived acute poisoning search should be made for the symptoms described, for sugar and albumen in the urine, and a spectroscopic examination of the blood made (see later). In obscure and slight cases examine carefully such reports as there are, enquire of the fellow workmen, examine the site, analyse the air, observe the behaviour of birds or mice placed at the spot. Do not forget careful search for other morbid causes (alcoholism, syphilis).

Diagnosis is still more difficult in chronic cases, especially in such cases when they are described as slight. Remember the important role often played by other factors or the other compounds in the gas containing carbon monoxide. Remember also that the spectroscopic examination of the blood is a method insufficiently sensitive for determining small quantities of carbon monoxide (i.e. when it does not exceed one-seventh of the total haemoglobin). Absence of notable traces of carbon monoxide in the blood does not prove absolutely that the patient has not died of carbon monoxide poisoning. Sometimes victims are withdrawn still living from the fateful surroundings only to die after having eliminated entirely what might be called the fixed carbon monoxide.

Similarly account must be taken (but with a grain of salt) of the results of the analysis of the air of the place, because it can happen that the individual who has succumbed was found still alive when the atmosphere had ceased to be dangerous. Often it is very difficult if not impossible to visualise the conditions under which the accident has happened. Certain factors are not slow in disappearing, like the gas itself, and others escape altogether.

**DEMONSTRATION OF CARBON MONOXIDE**

A. In the air:

1. For qualitative examination:

   1. Make the air bubble through a solution of chloride of palladium or expose filter paper soaked in palladium chloride by means of a platinum wire in a jar containing 10 litres of the air under examination. The surface of the paper becomes covered with a black film after some minutes if the air contains about 0.5 per 1000 of carbon monoxide and only after 12-24 hours if the proportion of carbon monoxide per 1000 is 0.05. The reaction is not characteristic because ammonia, hydrogen sulphide and acetylene can give it.

2. Reactions based on the stability of HbCO, among which the following will suffice:

   a. Shake one part of blood (diluted with 20 parts of water) with an equal quantity of a solution of caustic soda (30 per cent. strength); a red coagulum is obtained. At first there is a whitish turbidity, then a reddish coloration or a fiocculus, the precipitate separates and the liquid remains slightly pink. At the end of 24 hours the precipitate redissolves and the liquid becomes bright red.
(b) Weizel’s reaction: Shake 15 c.c. of a solution of blood (10 c.c. of blood and 40 c.c. of water) with 1 c.c. of a 10 per cent. solution of chloroform from a dropper and 5 c.c. of a mixture of 1 volume of glacial acetic acid and 2 volumes of water. The precipitate which forms after agitation is, in the case of normal blood, blackish brown and with the HbCO blood intense bright red.

(c) Another Weizel reaction: 10 c.c. of blood are treated with 15 c.c. of a 20 per cent. solution of ferro-cyanide of potassium and 2 c.c. of a mixture of one volume of glacial acetic acid and 2 volumes of water. The precipitate which forms after agitation is, in the case of normal blood, blackish brown and with the HbCO blood intense bright red.

(d) Spectroscopic examination of the blood: Properly used the spectroscope enables a positive statement to be made as to the presence of carbon monoxide in the blood, but a negative result is not sufficient to conclude that the gas is not present. In the spectrum bands D and E two absorption bands are seen—not so close to the D line of Fraunhofer as that of HbO. The space between the two bands is fainter in the case of HbCO. When reduced (with ammonium sulhide) the two bands do not give place to the single band of Stokes, as happens with HbO (a preparatory reaction, this, but very sensitive). For details of spectroscopic researches the reader is referred to special treatises.

II. Quantitative examination.

The amount of carbon monoxide in the air can be determined by the method with chloride of palladium or that of iodine pentoxide heated in a bath of air to 90°. The iodine set free is dissolved in some c.c. of chloroform from a dropper and colours it red. In passing 1 litre of air per hour the amount of carbon monoxide is estimated (after 4 litres of air have been aspirated) by the tint of the chloroform when compared with a range of shades sent out with the apparatus (apparatus of Levy and Pecoul). An apparatus suggested during the war by Desgrez and Labat as a colorimetric scale is made in a test tube similar to the scale tubes of 1 c.c. of a solution of potassium citrate or 0.05 per cent. sodium fluoride. 0.1 c.c. of the blood to be examined and 1 c.c. of equal parts of 1 per cent. tannic acid and 2 per cent. pyrogallic acid. Comparison is then made with the control scale. They have put up in a small box the equipment necessary for carrying out the reaction.

Prophylaxis

(See article “First Aid”)

The medical man alone should be the judge as to whether treatment should be varied in particular cases. But certain measures are common to all cases of poisoning by gases and fumes: e.g. eliminate if possible the cause of the poison, remove the victim from the noxious atmosphere (bearing in mind that rescuers can even become affected at considerable distances — more than 15 meters), slight anaesthetisation with ether where convulsions occur; artificial respiration (see “First Aid”) and prolonged inhalation of pure oxygen; keep up the circulation by friction of the skin; diaphoresis, etc.; bleeding, injecting caffein, camphor, etc. Recently (1923) the advantages of transfusion have been pressed; it should not, however, be done in cases that are in extremis. The above treatment, even in desperate cases, has given surprising results. But when poisoning has gone on for a long time and is profound, failures are comprehensible.

In poisoning by carbon monoxide the HbCO, stable as it may be, can be displaced by the use not of oxygen pure but oxygen containing 5 per cent. of carbon dioxide. Experiments carried out
enable one to say that this mixture excites deep and rapid respiration and makes elimination of carbon monoxide 5 or 6 times as quick as when normal air is employed, even when the victims have 30-40 per cent. of their blood combined with carbon monoxide.

Persons affected who are not attended by medical men should be made to inhale pure oxygen for 20-40 minutes at least. But every surgeon should use the O and CO₂ mixture, administered as early as possible.

Quite recently (1924) a new German preparation, "Lobelin Ingelheim", has been reported on favourably by the Imperial Health Office which claims to stimulate the respiratory centre in the bulb paralysed by carbon monoxide without affecting other organs. After intramuscular or subcutaneous injection of 3 to 10 mg., or in dramatic cases after intravenous injection of 3 mg., recovery is said to be very rapid. If the heart's action is embarrassed the usual cardiac therapy is brought to bear. Lobelin was used in cases of carbon monoxide poisoning following on a coal dust explosion in a German mine in 1923. The Ministry of Commerce is continuing its researches into the product.

The measures to be taken vary with the different industries (see each industry). In addition to the usual precautionary measures against toxic gases such steps should be taken as make for good ventilation and efficient exhaust in workrooms, periodic and methodical control of the heating apparatus, distribution of gas, taps, and leaks in pipes. Before cleaning operations are carried out or flues and pipes underground entered there should be preliminary energetic ventilation, and workmen should always be made to carry suitable respirators. (See article referring to special industries, e.g. "Mines ".)

If the precautions are insufficient to protect the men against prolonged inhalation of carbon monoxide (especially in minute quantities), redaction in the hours of labour should be considered.

As indicators of risk use should be made either of special apparatus (colorimetric indicator) or of canaries or mice which are very susceptible to carbon monoxide (symptoms shown with 0.0012 per 1000).

Workmen should be instructed as to the risk of poisoning and of the measures to take both at work and in rendering first aid.

**Legislation**

For the protection of women and children see "Gases (Industrial) and Fumes ".

Compulsory notification: Netherlands and Switzerland (which countries treat carbon monoxide poisoning as an accident).

Compulsion is dealt with in the German Bill and may be considered as included in the general heading adopted by the legislature of Missouri (1913—" Poisoning by toxic gases ") and that adopted by the legislature of Ohio and Massachusetts (" all illnesses caused by occupation ").

Acute poisoning is generally treated in law as being an accident.

It is included in the lists of diseases subject to compensation in the following countries: Finland, Germany, New York, Queensland, Switzerland, U. S. S. R., and Western Australia.

**Bibliography**

See especially the work of L. Lewin: Die Kohlenoxydvergiftung. Ein Handbuch für Mediziner, Techniker und Unfallrichter. Verl. J. Springer, 1920. (A volume of 380 pp. where the question is analysed in most detailed fashion from the point of view of the technician, the chemist, the toxicologist, the clinician, and medico-legal expert.)


See also the Bibliography of Industrial Hygiene, published quarterly by the International Labour Office.
anhydride are formed. It is the least toxic of the series of organic chlorinated substances adjacent to chloroform. It appears nevertheless with the latter product in certain orders regulating the sale of poisonous substances (Kohn-Abre). Carbon tetrachloride dissolves resins, gums, and fats.

It is got by the reaction of chlorine on carbon disulphide in the presence of a catalyst such as iodine, antimony, or aluminium chloride, or by the action of sulphur chloride on carbon disulphide in the presence of powdered iron, the sulphur being again transformed into chlor-ride by the action of the chlorine. It is also got by direct chlorination of ethylene.

The crude tetrachloride is purified by washing in dilute rectified soda.

**Sources of Poisoning**

**In course of preparation.** — The workers may be exposed to the combination of chlorine, carbon disulphide, and methyl chloride.

**In course of usage.** — (1) In the rubber industry, where it is used alone or mixed with other products in the preparation of rubber elements or mixtures in place of carbon disulphide, which is more poisonous and more inflammable, though less expensive. When the mixing is done by hand in open receptacles, there is risk of the fumes being inhaled. In modern installations this operation is generally effected in mixers. The workers engaged in filling the tubes with mastic or cement are also exposed to a similar risk. (2) In using the product as a solvent of acetate of cellulose, in the preparation of varnish for aeroplane wings. (3) In dry cleaning. (4) In making fire extinguishers (under the name of “pyrene”). Fieldner and Katz report that the use in mines and enclosed places of carbon tetrachloride extinguishers in the absence of sufficient ventilation may cause liberation of fumes containing not only ordinary products of combustion such as carbon dioxide and carbon anhydride, but also carbon tetrachloride, hydrochloric acid, and phosgene in such quantities that anyone exposed for five or ten minutes to the fumes may suffer, if not from serious effects, at least from persistent discomfort.

**Toxic Action**

Industrially carbon tetrachloride would not appear to have a powerful action. According to Marshall and Starr (1898), it exercises on the circulation and respiration the same toxic action as chloroform, only stronger.

According to other authors (Waller and Veley) it is twice as toxic. Lehmann, on the contrary, on the basis of laboratory experiments, says it is only half as toxic in strong doses, and equally toxic in small doses. Ramhusek considers that its narcotic action is half that of chloroform, but that it is much more irritating.

Rabbits can acquire chronic poisoning from it, and generally die after three or four days of bronchitis or broncho-pneumonia after 8-10 mg. inhaled during eight hours. Five to 10 mg. may be inhaled during six and a half to eight hours without other ill-effects than torpor, weakness, and semnolence. With 20 mg. a strong semnolent effect is noted amongst animals; 40 mg. cause narcosis preceded by sneezing, irritation of the eyelids, loss of equilibrium, and muscular contractions; 60 mg. cause impotence, and at the end of seven hours complete loss of consciousness; 80 mg. bring on profound narcosis, and 240 mg. death after two hours.

According to Fros, 15 mg. per litre of air cause, in the case of human beings, narcosis, headaches, and vomiting. According to Graham, carbon tetrachloride causes, in the case of animals, more pronounced necrosis of the kidneys than that due to chloroform. The explanation of this is found in the liberation of a greater quantity of hydrochloric acid during decomposition of the constituent products of the substance, similarly to what occurs in the case of phosgene poisoning, poisoning by tetrachloride being in certain conditions true phosgene poisoning.

**Statistics**

Starr (Ohio) reports that 22 out of 27 women workers engaged in a millinery establishment presented signs of poisoning after using a mastic containing 66-70 per cent. of carbon tetrachloride, 34-30 per cent. of benzene, and traces of carbon disulphide. Specific symptoms not having been observed, however, there is a possibility that the troubles noted were rather to be traced to the benzene, though the irritation of the eyes and the throat noted amongst the workers seemed more marked than is usually the case with benzene.

In Germany in 1923, in the Erfurt district, a case of very marked narcosis was reported as affecting a man engaged in gluing soles with a mastic, having as its solvent a liquid chiefly constituted of carbon tetrachloride. In 1924, in the Düsseldorf district, 4 cases of poisoning were reported amongst workers engaged in coating barrels and vats with a product containing carbon tetrachloride. The
sufficient to produce in crises, but thinks that a few mg. per litre of air only suffice to produce in an enclosed space, unless the person using them is provided with a gas mask. The formation of phosgene is held to be due in great part to the action of steam on the carbon tetrachloride, and the oxidation of the latter is not thought to constitute an important factor in this formation. It results therefrom that danger in the use of these extinguishers depends on the humidity of the atmosphere, and the greatest precautions should be taken either where water is used simultaneously, or where it is applied later for watering the smoking material.

Protective measures for workers exposed to the inhalation of carbon tetrachloride fumes are similar to those outlined for substances which liberate toxic fumes.

LEGISLATION

No special legislation exists in relation to this product. In general the legislation which would apply is that relating to the chemical industries (see article "Chemical Trades").

Injuries due to carbon tetrachloride are liable to compensation as an occupational disease in Switzerland and in the countries which grant compensation for disease due to gases and fumes.

Carpets, Hangings, and Table Covers

French: Tapis. — German: Tapeten; Teppiche. — Italian: Tappeti; Tappezze. — Spanish: Alfombras; Tapices.

Woven tapestries are made by hand on different kinds of looms varying according to the product required. There may be distinguished tapestries for hangings, high warp tapestry (Gobelin), and low warp tapestry (Aubusson, Beauvais, Felletin); table covers and various covers used in furnishing.

Amongst carpets and covers made of wool may be distinguished Aubusson carpets, plush or pile carpets (carpets with knotted stitch, oriental or Turkey carpets, Smyrna carpets, high warp pile carpets, long pile carpets), cut pile carpets, printed warp carpets made by previously printing the threads in colour according to the design required. Amongst the cheaper categories of carpets may be mentioned felt and pile carpets and carpets made from various printed materials.

The raw materials used are very different according to the kinds of carpet required: wool, cotton, hemp, flax, jute. The wool used in the carpet industry usually consists of short, thick ends.
Several different fibres are often used in making the same carpet. In certain establishments the raw materials are sorted, carded, twisted and woven whilst in others they arrive completely prepared. The bales of thread are opened and passed to the weaving room. Once woven, ordinary factory-made carpets undergo a shearing process — which serves to equalise the length of the different threads — and then they undergo brushing, which serves to raise the pile of the carpet. Amongst the finishing operations should be mentioned “rentering”, which consists in damping with the needle the parts missed in machine manufacture, and “hurling” or “picking”, which consists of removing with pincers irregularities, knots, and straw from the carpets.

Needle run tapestries are embroidered tapestries done by hand, worked on canvas stretched on an embroidery frame and sewn with thread (wool, silk, etc.) of different colours, either by counting the stitches in copy of a printed design or by following a design first printed on the canvas (see article “Lace”).

Beating of carpets is rarely done by hand and is most frequently executed in closed beating machines. In the case of certain carpets, the operation is completed by dry cleaning with suitable solvents (see article “Dyeing”).

Sources of Risk

The possible sources of risk in the carpet industry are as follows:

Dust. — The weaving of carpets involves the same risk from dust as is met with in the textile industry. The opening of the bales of thread, freeing these from dust on arrival, shearing and brushing of carpets after weaving and thereafter beating are particularly dusty operations.

Apart from the irritant action exercised by dust, it offers particular risk when toxic colouring agents have been used in dyeing the threads employed. In order to diminish this risk, the State of Massachusetts has, since 1901, limited to 0.10 grains per square yard the amount of arsenical pigments to be used; aniline colours have besides been substituted to a large extent for chrome and lead colours.

Mention should be made of the risks from infectious diseases in the course of carpet manufacture: cases of anthrax due to contaminated wools in the course of the beating of old carpets which have come in contact with various germs in the places in which they were used.

Other sources of risk derive from the working posture, from the concentration required for avoiding and detecting defects, whilst further causes of ill-health are connected with unsatisfactory working conditions (insufficient lighting and ventilation and overcrowding of workshops, etc.).

It is finally necessary to refer in passing to exposure to fumes from toxic solvents when carpet beating is completed by dry cleaning (see article “Dyeing”).

Statistics

Available statistics are very few in number. The Factory Inspection Department reports anthrax cases and max which occurred in 1922 in a carpet factory in Saxony, probably due to infected wool. Thomson has reported several cases of anthrax amongst carpet weavers in New York. In a carpet factory at Yonkers, New York State, there occurred in 1927 3 cases of anthrax, 2 of which were fatal; these were also due to infected wool.

Neisser quotes 3 cases of poisoning by benzene amongst workers occupied in cleaning carpets.

The weaving of carpets is a difficult operation, but nevertheless the mortality rate amongst workers is comparatively low in relation to that of other industrial groups in the textile industry. The British statistics show a relative mortality of 873, or 8 per cent, below the standard figure. The mortality figure for tuberculosis is 22 per cent, above the average and for other diseases of the respiratory system 11 per cent, higher than the average. Hoffmann’s statistics based on 155 deaths amongst workers in carpet factories show a relative mortality of 15.2 per cent, to have been due to phthisis and 16.9 per cent, to other diseases of the respiratory system.

Pathology

For pathology see the following articles: “Textile Industry” (for diseases due to dust) and “Solvents” and “Dyeing” (for diseases due to the solvents used).

Hygiene

The usual precautions should be taken against the liberation of dust when the bales of thread are opened and freed from dust, as well as in the course of the operations of shearing and brushing the carpets. Closed apparatus or efficient systems of localised exhaust should be used where appropriate, and completed by good general ventilation.

Carpet beating establishments in certain countries (France, for instance) have been brought within the category of scheduled establishments (dangerous, unhealthy or noxious trades — causes of risk: noise and dust), and are, in consequence, liable to a certain number of restrictions: enclosing of the estab-
lishments within sufficiently high walls to prevent the dust gaining access to houses in the neighbourhood, prohibition of beating in the open air, compulsory installation of impermeable flooring for the workshops, compulsory coating of the walls with a smooth finish and even the application of a coating medium dissolved in oil; compulsory beating by means of mechanical beaters hermetically closed and provided with powerful dust exhaust so disposed as to prevent the dust causing inconvenience to the workers or gaining access to the exterior; compulsory impermeability of the flooring of courts in which beating by hand may be carried on; frequent washing with a hosepipe of the flooring, walls and glass frames placed above the beating tables; machinery to be kept at a distance from common walls with a view to avoiding inconvenience for neighbours; removal by drains of waste water from washing. The use of dust exhaust devices now makes it possible to replace very easily work of this kind done by hand by mechanical processes.

LEGISLATION

Decree of 17 December 1923 relating to the protection of workers in the manufacture of carpets in Kerman (Persia) and Baluchistan. — The chief measures prescribed are as follow: limitation of the working day to eight hours; fixing of the age of admission to work at eight years for boys and ten for girls; compulsory separation of boys and girls for the two sexes; prohibition of the utilisation of damp basements as workrooms for carpet weaving; compulsory provision of windows with southern exposure in order to provide adequate lighting, placing of weaving looms at a height of one metre from the floor of the workrooms with a sufficiently high seat to permit of the children carrying on the work under the best possible conditions; prohibition of employment or retention by owners of factories of workers affected with contagious diseases; monthly inspection of the factories by the chief of the health service or municipal doctor. In the case of contravention of the health and hygiene regulations laid down, these medical authorities are called upon to furnish a report to the competent authorities, who must immediately intervene.

It should be noted in passing that these measures were in part adopted thanks to the action taken by the International Labour Office, which in 1920 found it necessary to attract the attention of the Persian Government to the deplorable working conditions in which children were employed in the carpet industry of Kerman.

In other countries legislative provisions call for the exclusion of boys under six-

teen (Quebec, for instance) or of young persons under eighteen (France) from the operation of carpet beating when dust is freely liberated in the workrooms. 

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Celluloid

French: Celluloid; German: Zelluloid, Zellhorn. — Italian: Celluloid. — Spanish: Celuloide.

Celluloid was prepared industrially for the first time in 1889 at Newark (United States) by the brothers Hyatt; it is finding more and more and more numerous spheres of application because it is easily worked and may be put to many uses, particularly as a substitute for ivory, horn, tortoiseshell, amber, and bone.

RAW MATERIALS

Celluloid is an intimate mixture of weakly nitrated cellulose, natural or artificial camphor and alcohol.

Risk exists for the workmen who make or manipulate this product by reason of the easily inflammable nature of some of the materials used.

Cellulose is derived from cotton, paper, or textile; the acids used are nitric and sulphuric; the solvents are ethyl alcohol which is replaced for reasons of economy by methyl alcohol, petrol, benzol, ether, acetone, acetate of amyl, etc., and even by such mixtures as amyl acetate with alcohol, and petrol or benzol with methyl alcohol.

Celluloid factories very often rectify the used alcohol but this operation is usually done without danger in automatic apparatus.

When natural camphor reaches a high price it is replaced by different substances, such, for example, as synthetic camphor, phenyl phosphate, or ethyl phthalate.

As pigments, colours may be used with a chromatic base, aniline, and bronze-colours, some properties of which may cause skin irritation. As materials for filling up, dioxide of zinc, gelatine, colza oil, etc., are used. In order to diminish its inflammability, celluloid is treated with salicylic acid, magnesium chloride, sulphate of aluminium, etc. The composition of celluloid and its properties are fairly variable.

Generally the celluloid of commerce contains (according to Will and Dubovitz) 50-70 per cent. of nitro-cellulose, 15-35 per cent. of camphor, and 0-15 per cent. of colouring and filling up materials. Celluloid is inflammable and unstable, usually in proportion to the strength of nitro-cellulose it contains. These properties
are, on the contrary, diminished when the strength of the camphor increases: the celluloid becomes stabilised. Without the addition of colouring materials celluloid is almost colourless; in thin sheets it is as clear as glass and quite transparent. Its specific gravity is from 1.3 to 1.4. In the cold state it is unaffected by most chemical products and is very solid. It cannot be broken, but fairly thick pieces can be cut, planed, sawn and twisted, like wood, horn and amber. Thin slabs and small sticks it can be bent and rolled, but afterwards it resumes its original shape.

Heated to 60-65° C., celluloid acquires plasticity which is indispensable for numerous purposes, e.g., for the making of dolls; this plasticity increases with a rise of temperature.

Celluloid is used particularly in the making of combs, toothbrushes, dentures, the handles of walking sticks and umbrellas, ornaments used in hair dressing, collars and cuffs, buttons, boxes, pianoforte keys, pipes, toys, stereotype plates, artificial flowers, and all kinds of articles of practical utility.

Besides all these uses it is constantly employed in the manufacture of films (with nitrocellulose obtained from a more highly nitrated celluloid) and, on account of its solubility in acetone and other solvents, in the preparation of: cement for shoes and of other mastics, such, for example, as the lacquer "Zapon" (solution of celluloid in acetone and acetate of amyl); waterproof or oilproof coatings, used for the wings of aeroplanes; and also of lacquer for various objects (see also article "Nitro-cellulose").

**Industrial Operations**

The principal operations are the following: preparation of nitrocellulose, and bleaching; reduction to a fine powder; introduction of colouring matter; preparation of camphor or its substitutes; mixing of nitrocellulose, camphor and the solvent; introduction of stabilisers if the product is required to be transparent; partial drying of the paste; recovery of the solvent; desiccation under pressure; cutting up and moulding; final drying; and utilisation of waste.

The cotton required for the manufacture of cellulose is prepared in special factories, the celluloid works receiving the cotton already defatted, bleached and washed.

The nitration of cellulose is carried out as for the preparation of nitrocellulose used for making artificial silk (see articles "Nitrocellulose" and "Artificial Silk"). Cellulose nitrate six to nine times with a strength of 10-12 per cent. of nitrogen seems to be that most suitable for the manufacture of celluloid.

The nitrocellulose is hung up to dry and, after two or three crushings, there is added to it camphor and opaque and colouring materials. The crushing is continued until the mass becomes quite homogeneous.

In order to expel the water which has been used in the mixing, the mass is at this stage moulded in a hydraulic press; in this way are obtained sheets having a thickness of some millimetres. These sheets are separated by thin layers of coarse blotting paper and are subjected to the energetic action of the hydraulic press; this operation is repeated until the desired desiccation is obtained, changing the blotting paper each time. The sheets, which have a thickness of 3 mm. and are cut, planed, turned, polished, and burnt and amber, are broken up by means of cylinders furnished with teeth. The broken material is brought into contact with pure alcohol and mixed with toluene for twelve hours. Colours, soluble in alcohol, are added at this stage if it is desired to colour the paste.

After maceration the mixture is passed into a rolling mill heated to 50-80° C. and converted into homogeneous sheets which, superimposed in several patterns, are compressed for twenty-four hours by means of a powerful hydraulic press heated to 80° C. by the circulation of steam. The sheets are thus welded together and form blocks of celluloid which are cooled at once in water-cooled vats. According to the German method, the camphor is first dissolved, chiefly in alcohol, allowed to settle and cool, then the solution is poured into vats which contain dried nitrocellulose. The contents are mixed; the vat is covered again for a certain time, and then the whole is passed into a mixer at 90° C. in order to ensure the closest possible blending. The vapours of alcohol are removed and recovered in a condenser. After purifying, the product is subjected to a hydraulic press and then rolled flat. The rolling, however, gives a product riddled with bubbles of air which must be removed to obtain a homogeneous celluloid. This is done by submitting the sheets to the hydraulic press (see above).

The working of celluloid resembles that of india-rubber; sheets and blocks are cut, planed, turned, polished and shaped by means of heat to preserve the shape obtained.

For polishing celluloid, in addition to heat and pressure, sheets of brass are used, placed between the sheets of celluloid.

The sheets and moulded articles are dried in a stove at 60-65° C.; stoving
CELLULOID

may be required for several months, depending on the thickness and the nature of the articles. Celluloid is then worked like wood. A product which has an analogous composition and which in addition contains castor oil is "pegamoid", used for making artificial leathers, oil-cloth, etc.

Recovery of Celluloid

Some works do not chiefly engage in the manufacture of celluloid or celluloid articles, processes which may exist alongside, but carry on recovery of the worn-out article. This industry makes use of the fact that celluloid deteriorates by losing camphor. After soaking in a tank of hot water and macerating in a solvent, camphor and colouring materials are added to waste picked over and reduced to pulp. It is mixed and rolled white hot; thus sheets of celluloid are obtained, which are welded together by hydraulic pressure. The product is a celluloid of second or third quality.

Dangers

Dangers from fire and explosion arise from the raw materials used in this industry, i.e. cellulose, acids and solvents. Cotton, paper, and tissues may cause fires, especially during the operations of drying and weighing. Acids may explode in reservoirs or retorts, or become decomposed, especially when nitric acid is slightly heated — by exposure to the sun for example — or mixed with other concentrated acids, or may set free nitrous and sulphuric fumes when they are subjected to severe jolting: in acid stores, nitration apparatus, presses, drying rooms, or during the transport of freshly prepared nitrocellulose.

Solvents may easily cause fires or explosions, in stores, during transport, in the processes of dissolving camphor, nitrocellulose or scrap celluloid, and of crushing and pressing.

Alcohol is only used when dehydration of nitrocellulose is carried out. The danger is serious not only when it is poured upon nitrocellulose, but also during the processes of pressing and drying. The rectification of alcohol is not dangerous, for it is automatic. The danger is only real when cracks in the piping or apparatus lead to chance accidents.

Bronze colours may also cause fires or explosions; it is notorious, as a matter of fact, that certain of them are spontaneously explosive. As the quantity of colours used is very small, the danger is not great. It is however advisable to prevent the raising of dust in the workroom by damping the colours with alcohol.

As regards celluloid itself, it is practically insensitive to pressure, shock, shakings and ordinary lighting. According to Will, it is also equally stable when subjected to an electric current. It does not exhibit any great susceptibility to moderate heat, when the preparation has been properly carried out, using sound raw materials.

On the contrary, celluloid takes fire easily in contact with incandescent bodies, such as incandescent lamps and the electric arc, as well as with naked lights. Once alight it burns rapidly, with leaping jets of flame, producing a high temperature and may catch fire, according to Will, 1,500 to 2,000° C. Quite apart from the composition of the celluloid, inflammability increases with its state of division and the thinness of the sheets. For this reason the risk of combustion, even from electric sparks when they are strong enough, or of rapid spread of the fire is very great, particularly, for example, with the dust from polishing. In some circumstances, notably with varieties insufficiently stabilised, the sensitiveness of celluloid increases a good deal, up to decomposition when the temperature is high. Sometimes decomposition occurs at about 100° C., the body then catches fire with an explosion. With good qualities of celluloid this phenomenon only occurs between 150-170° C. Combustion is usually very rapid and accompanied by bursting jets of flame and the setting free of poisonous gas which is explosive when mixed with air. Once the decomposition has commenced, it may very often continue without flame even after apparent extinction of the fire. Explosive gases may in a short time reach situations of rapid spread of the fire. As regards celluloid, sometimes passing by exhaust ducts for the extraction of dust. If, for any reason, they become ignited, they may cause serious damage. This decomposition, which gives off an evil-smelling gas, continues when burning, properly so called, is extinct. According to circumstances an explosion may still be feared even when the celluloid which is supposed to be in course of decomposition has been immersed in carbonic gas or steam.

The limits of explosion for this gas with air are 9 to 40 per cent. It is composed especially of carbon monoxide and minute carbon dioxide, 14 pounds of nitrogen hydrogen and methane, as well as of small quantities of hydrocyanic acid. According to
Lodemann, combustion of a gramme of nitrocellulose film sets free about 600 c.c. of gas, of which 260 c.c. are carbon monoxide, 150 c.c. oxide of nitrogen and 5 c.c. hydrocyanic acid. According to the earlier tests of Will, the proportion of hydrocyanic acid is considerably higher.

The English enquiry of 1913 showed that the gases disengaged by the burning of films protected from the air contained 26.3 carbon monoxide, 7.3 carbon anhydride, 0.7 carburetted hydrogen and 28.5 dioxide of nitrogen.

It is well known, however, that during combustion, cellulose sets free carbon monoxide in particular.

One thousand grammes of burning celluloid, protected from air, at 0° C. and 760 mm. of pressure, set free 17 to 18 litres of gas, that is to say, from 4 to 7 litres of carbon monoxide, 3 to 4 litres of carbonic dioxide, 7 to 9 litres of oxide of nitrogen, 0.7 grammes of hydrocyanic acid, as well as traces of acrolein and camphor.

In the presence of air, burning celluloid liberates greater quantities of hydrocyanic acid (about 1 to 2 grm.) as well as oxide, dioxide and tetraoxide of carbon.

Kockel has shown that combustion of 5 grammes of celluloid wool, which is about the weight of a little comb, sets free sufficient hydrocyanic acid to kill a man. Under such circumstances it is not astonishing that very serious poisonings may result from conflagrations of celluloid. But this opinion is not shared by most experts, who consider that the toxicity of the fumes is essentially due to the presence of carbon monoxide. Will and some Austrian experts record that there are already many kinds of celluloid which under certain conditions, in particular when under poor quality and spontaneously inflammable at about 100° C. From this point of view the following experiment is particularly important: a little piece of celluloid was put, with air freely circulating, on a glass tube, through which was passed a current of steam at 100° C. The specimen at once became soft, then give off a great quantity of gas, and at the end all that was left was a carbonised mass resembling a sponge. Flame only appeared when the celluloid was placed on the glass tube wrapped in paper: this paper became carbonised and, in consequence of better contact with air, combustion occurred with the appearance of flames. These experiments furnish some explanation of how decompositions and flaring, due for example to heating by steam and appearing at first incomprehensible, can be produced. There is no need to infer always that the celluloid was wrapped in paper, but it may very well happen that some rag or paper were deposited, along with celluloid, for example, in a waste-bin. Allowance must also be made for some very easily inflammable papers, for example grease paper used for lunches, being deposited in the side of celluloid debris on a steam heater or in its vicinity. The probabilities of fire are still greater when heating pipes are filled with steam at high pressure and in consequence overheated.

Celluloid fires can also be caused by very hot gas escaping from internal-combustion engines; by heat radiating, for example, from incandescent lamps or heated bearings, and, in some circumstances, by driving-belts becoming charged electrically. Its handling and shaping are more dangerous than its manufacture. Fires have been caused by coveringing machines, saws, and emery grinding wheels revolving very rapidly (sometimes during the removal of the layer of hard celluloid covering these wheels), or by sparks from electric fuses, or even from drops of melted metal falling from electric lamps. Fire has sometimes been due to the addition of large quantities of organic or inorganic substances to certain varieties of celluloid in order to obtain a watered cloudy appearance or other effects of colouration. Sometimes also little splinters of steel, sand or flint or nails become embedded in celluloid owing to flaws in manufacture. When worked with saws and reamers, or on wheels revolving very rapidly, sparks may be produced and set fire to the dust produced by these tools which is particularly unstable and inflammable.

When celluloid is of poor quality it sticks to the grinding wheels and forms a hard layer. It is necessary then to scrape it from time to time by holding against the wheel a piece of flexible sheet iron. This operation is not done without sparks which may in some cases cause fires.

This danger exists during reaming and sawing, in brush and comb factories, sometimes even when the upper part of the saw is being cooled by water and the lower part is plunged into oil. In one Swiss comb factory 33 deaths occurred, that is to say, a tenth of the staff employed: the extent of the catastrophe was determined not only by the great quantity of celluloid which took fire, but also by the bad arrangement of passages, doors and windows, with a lack of exits and especially by the defective state of the dust exhaust.
Radiant heat has been a cause of serious accidents, e.g. manufacture of celluloid, and chiefly during pneumatic sprinkling or immersion, workmen often experience torpor, giddiness, headaches, attacks of coughing, oppression, and nausea, especially at the commencement of work. In places where the ceiling is high and which are well ventilated, these effects are scarcely noticeable (Zäuner).

Dermatitis caused by the use of chlorid of lime or chrome colours, or aniline has also been described (Zäuner).

Heim, Agasse-Lafont and Feil have studied the morbid manifestations of workmen employed in making and handling celluloid. The investigation was carried out in a workshop for shaping celluloid, an annex to an accumulator factory, where small boxes for holding pocket accumulators were made.

After having excluded the existence of lead poisoning, the authors turned their attention to morbid manifestations due to celluloid and its solvents. The workmen used celluloid dust which contained camphor, and a paste containing acetate of amyl and acetone.

Nearly all the workmen complained of headaches, worse during the first months of work and especially towards the end of the working day. Medical examination only revealed the existence of eosinophilia equal to or above 4 per cent. which the authors attributed to acetone or acetate of amyl, whilst the headaches were caused by camphor.

Some control investigations, made upon other workmen handling the same substance (film perforators), confirmed the result. However, the authors do not consider that the haematological condition in question could be interpreted as characteristic; but it might well be an indication of a poisoning or at least of a reaction of the system to the poisons in question. Boulin has described a case of lead poisoning due to the use of a paste containing minium (red lead) and used to give celluloid the appearance of tortoiseshell.

Persons who have been the victims of fire or explosion from celluloid have been noticed to suffer from vomiting, cyanosis, dyspnoea, sugar in the urine, vertigo, and headaches which last a long time. The picture is characteristic of poisoning by carbon monoxide. In the corpse the blood is a bright red.

HYGIENE

All these occurrences and the investigations which have been made into
the causes of these accidents have stimulated enquiries into means of prevention and have raised the question of the preparation of substitutes for celluloid, which is too easily inflammable and so dangerous on account of its gas of decomposition.

These attempts have not been without result; there are actually a very large number of substitutes for celluloid: galalith, secourid, bakelite, faturam, gommalite, elfenite, cellone, cellite, etc. In spite of certain very excellent qualities, these substitutes are, either from one point of view or another, inferior to celluloid, for example, as regards the ease with which it can be shaped, resistance to light, air and humidity, or the possibility of colouration. They are sometimes less elastic, they stick more easily to tools and cannot be so readily shaped as celluloid on treatment with warm water, or stuck together, or welded by means of acetone. Some change colour in the air and cannot be shaped into slabs or tubes. Others are not only dearer to prepare, but they are also harder and more brittle.

An attempt must therefore be made to avoid in another way the dangers which the use of celluloid presents and the following precautions seem the most deserving of attention:

(1) During the construction of a factory account must be taken, from the laying of the first foundations, of dangers from fire, decomposition and explosion. Workshops which seem too large must be subdivided; and passages, doors, windows and emergency exits must be conveniently arranged. A large number of fire extinguishing appliances must be provided, and very great care exercised in the arrangement of warehouses, especially as regards stores for scrap. Holding unduly large stocks must be avoided.

(2) Particular care must be exerted during the installation and use of heating and lighting apparatus, including electric apparatus, as well as during the use of acetone, benzol and other inflammable products.

(3) Different workplaces must be screened off so as to prevent fire from spreading.

(4) The installation and also the use of reamers, saws, emery wheels and other appliances which may give off sparks, must be supervised. It is advisable also to take precautions against overheating of driving shafts and also against the production and spread of conflagration by driving belts or exhaust apparatus. It must be possible to shut off chambers for dust and shavings installed in the basement which are difficult to supervise and almost impossible to clean completely.

Official investigation undertaken in Germany as to the advantage or disadvantage of extracting dust in celluloid works has not completely solved this problem. In practice it is necessary to consider, on the one hand, the evacuation of dust, and, on the other, the danger from fire spreading. It has been established that flames can spread in exhaust ducts against the current of air and that they may thus come to set fire, under certain circumstances, to dust which is in front of the exhaust opening. The objection may be made and must be borne in mind that good installations prevent precisely any dangerous accumulation of dust and exclude in consequence risk from fire. After some accidents it has been reported that danger from the production of gas and decomposition is much greater with celluloid or finely divided debris than with tubes, sticks or other bigger pieces.

(5) Apparatus should be ready and in order for protection against gas or for reviving victims, so as to be able to assure first aid in case of fire.

(6) So far as is possible, quarters, workshops or offices occupied by a number of persons must not be located above processes which present a great danger of fire.

Among extinguishers the “Minimax” apparatus has sometimes shown itself efficient, but, on other occasions, has not worked effectively. It is the same with the “Grinel” vaporisers. Dry extinguishers have sometimes been used successfully. Extinguishing bags (sacs d’extinction) have given very good results, particularly in fighting danger from sparks arising during reaming, sawing, or other mechanical process. Similarly pieces of cloth, kept ready in a bucket of water placed in the workshop, have been used with success, provided that they are spread out immediately on the place where the fire originates. Moreover, decomposition and dangers which arise therefrom are not always completely avoided even when the measures taken appear to have been adequate. In the manufacture of such articles of celluloid as combs and large teethed-combs (for wool combing), soaking in acetic acid, generally in acetic acid, in order to polish the internal surfaces of the teeth, is a disagreeable operation, especially in
winter, for the work is done in hot and stuffy workshops. The vats containing the acid solution should be placed under an exhaust shaft with an exhaust flue and supporting a drying board on which are placed the dipped combs. The heating should be effected by a stove pipe coming from the outside, while the exhaust draught must be strong enough to prevent lacrymation and smarting of the eyes.

Of course it is not enough that all these arrangements be installed, but it is essential that they be kept in good order and absolutely ready for use, and it ought not to happen, as has sometimes been the case, that the extinguishers or buckets have not been properly filled or are not ready to hand, or that there is not sufficient pressure in the water mains.

**Legislation**

Knowledge of these dangers has naturally led to official measures for dealing with them and most countries possess arrangements for the prevention of fires and for safety in celluloid factories. Thus, for example, at Leipzig, following the fire of 1900, a committee consisting of representatives of the police in charge of buildings was set up and entrusted with the control and supervision of installations of gas, of lighting and for fire fighting. Later the Market Committee of the Chamber of Commerce had occasion to take up this same question, for it was necessary for the market to have sufficient stocks of celluloid.

In Austria, fires which broke out at Vienna and elsewhere led to very complete official investigations, as well as to publication of rules based on those investigations. The Austrian Ministerial Ordinance (1908) on celluloid traffic and celluloid articles and waste, which appeared following these events, comprised as many as 66 paragraphs. Almost at the same time there appeared in most of the States of the German Empire similar Ordinances more or less comprehensive. The "Collection of Instructions for the Protection of Workmen in the German Empire" quotes no less than 15 publications of this kind (pp. 179-180) among which must be noted the Bavarian Ordinances (of 9 and 23 March 1912) and the Prussian Ordinances (of 7 May 1910, 11 December 1911, and 24 April 1920), this latter being much fuller as regards films. Almost at the same time there appeared in most of the States of the German Empire similar Ordinances more or less comprehensive. The "Collection of Instructions for the Protection of Workmen in the German Empire" quotes no less than 15 publications of this kind (pp. 179-180) among which must be noted the Bavarian Ordinances (of 9 and 23 March 1912) and the Prussian Ordinances (of 7 May 1910, 11 December 1911, and 24 April 1920), this last being much fuller as regards films. Almost at the same time there appeared in most of the States of the German Empire similar Ordinances more or less comprehensive. The "Collection of Instructions for the Protection of Workmen in the German Empire" quotes no less than 15 publications of this kind (pp. 179-180) among which must be noted the Bavarian Ordinances (of 9 and 23 March 1912) and the Prussian Ordinances (of 7 May 1910, 11 December 1911, and 24 April 1920), this last being much fuller as regards films. The floors must be cleaned wet and there must be a supply of buckets of water for extinguishing purposes. Contractors are responsible for giving warning by means of notices to home workers of the dangers which the handling of celluloid presents.

**Great Britain**

On 28 November 1921 laid down Regulations for factories and workshops or parts of factories and workshops where celluloid is manufactured, manipulated or stored, or where articles are made entirely or in part of celluloid.

**Hungary**

On 28 June 1923 published a Ministerial Ordinance dealing with the construction and working of factories where celluloid is produced or handled and also for shops and depots of celluloid.

**Switzerland**

Provides measures of security by section 30 of the Factories Act (3 October 1914).

An Ordinance concerning the handling of celluloid, of celluloid articles and scrap was introduced in Czechoslovakia in March 1925.

The labour of women in celluloid factories is forbidden by the Austrian legislation.

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Cellulose


Properties

Cellulose, the principal constituent element of the cellular tissue of plants, of which it forms the skeleton, is habitually associated with other different encrusting substances, except in the case of cotton, where it is almost pure. The most important kinds of cellulose are ligno-cellulose (wood, jute) and pecto-cellulose (linen, hemp).

Chemically, cellulose is a hydrate of carbon with the formula \( (C_6H_10O_5)n \). In the pure state it is white, with a specific gravity of 1.54 with 6 to 12 degrees of humidity, which it loses at 100°C, re-absorbing them again in the air.

Fibrous and colloidal, cellulose is unaffected by air and water (a fact which explains its numerous uses). It is insoluble also in alcohol, ether, etc.; it resists fairly well the action of acid solutions, and even better, dilute alkaline solutions. Treated, however, by a 20 per cent. solution of soda lye, it is converted into alkaline cellulose \( \text{C}_{12} \text{H}_9 \text{O}_{16} \cdot 2\text{Na} \cdot \text{H}_2 \text{O} \), which easily loses its alkaline quality on washing in water, leaving the cellulose in the form of a hydrate: \( \text{C}_6 \text{H}_9 \text{O}_5 \cdot \text{H}_2 \text{O} \). Applied to cotton, this treatment makes the fibre more brilliant with a greater affinity for colouring matters (mercerising).

Alkaline cellulose fixes carbon bisulphide yielding xanthate or trio-carbonate of cellulose (the principle of the manufacture of viscose; see the article "Artificial Silk").

With nitric acid, cellulose yields nitrocellulose, which is a nitric ether, and with acetic acid, aceto-cellulose or cellite (see these articles).

Oxidising agents, especially when warm, yield an oxy-cellulose, which reduces Fehling’s solution. After bleaching by chlorine, therefore, the excess of chlorine must be got rid of with the greatest care to avoid the formation of this product. Cellulose dissolves in a 40 per cent. solution of zinc chloride; in Schweitzer’s solution (solution of copper oxide in ammonia) it is converted into the condition of oxy-cellulose up to 5 or 10 per cent. of the weight of the solution.

Generally in industry the term cellulose is given to the purified product — usually the extract from the chemical pulp.

The separation of the pure product from the compound celluloses is effected by treatment with bisulphites and alkalies. It is thus that it is usually prepared from wood pulp, especially when pure cellulose has to be used (as in silk-viscose, nitro-cellulose, etc.).

Processes

Cellulose is manufactured by two processes: one is mechanical, yielding the mechanical pulp, or wood pulp, or milled pulp, and the other chemical, i.e., the action of chemicals on the vegetable fibres, and especially on the wood yielding the chemical pulp.

Mechanical Pulp

The processes actually used date from about 1860, when Keller Voelter first tried them in Germany. They have been unceasingly perfected since then.

The raw materials are fresh fir of the best quality, aspen and poplar (which yield a white pulp with shorter and more expensive fibres than that obtained from the wood of conifere), etc. Pine wood cannot be used because of its content in resin, which makes the pulp liable to break. It can, however, be used alone or with fir to make what is called the brown pulp.

The wood is cut into small cylindrical pieces of about 50 centimetres: the bark is removed by a machine, and the wood pulped. The “pulp grinders” carry horizontal and vertical axes supporting grindstones against which the wood is pressed by hydraulic pressure of 7.5 to 8 atmospheres. Light pressure with slow rotation per unit of time gives a better quality of pulp, but not so large a quantity as is obtained by high pressure and rapid rotation. Machines recently put in use allow low pulping of the wood to be done in the direction of the fibre and thus to obtain a better quality of fibre, both longer and stronger.

Pulping is done under a stream of water either strong (cold pulping) or weak (hot pulping because normally it causes a rise of temperature between 30° and 80°C). The heat generated
facilitates the pulping and yields a longer and more supple fibre. The temperature, however, ought never to exceed 80° C., or else the pulp goes brown. The Behrend method subjects the wood to a preliminary treatment with low pressure and steam to soften it and facilitate pulping. A high temperature and the kind of wood used leads to a brown discoloration of the pulp which cannot be bleached, but is more resistant.

The pulp is then laid out in water, then sieved in a series of revolving sieves: a coarse sorter (which eliminating the large fibres, etc.), a fine sorter with transversal and centrifugal movement, which continues the elimination of impurities and the bundles of fibres that have not been separated. Sometimes the pulp is reground in a refiner (a fixed and a revolving grind-stone), and the mush thus obtained is again submitted to sorting and then led to a machine in which it is drained. This operates in such a way that when, by the rotation of the drum, a layer of drained pulp sticks to the outside and upper part of the cover, it is then led on to a felted belt which, again, directs it to rollers, where the greater part of the water still remaining is removed by pressure. The material, which adheres more readily to the iron than to the felt, rolls itself round the roller, in layer after layer, until it has attained suitable thickness.

A wood paste is thus obtained, containing about 70 per cent. of water, which is cut into sheets which, after passing through a hydraulic press, do not contain more than 40-50 per cent. water. This "commercial wet-wood pulp" becomes wood pulp if the content of water is reduced to 10 per cent.

These two products can be subjected to chemical treatment either before or after the moment when they reach the state of pulp and become named commercially "raw pulp" or "bleached pulp".

**Chemical Pulp**

At the commencement the process was essentially mechanical; then, boiling the paste was carried out without pressure, adding milk of lime and a little ash or soda lye. Later, boiling under pressure was done, which led to the development of the chemical process and the manufacture of chemical pulp. The raw materials used are straw, esparto grass, and wood (white fir, pine, poplar, aspen, etc.).

According to the nature of the fibre to be treated, the chemical pulp is made by the caustic soda method or the bisulphite. Other processes have been tried, but without yielding practical results, although some day one or other of them may play an important role.

1) **Caustic soda method.** — The disadvantage of the soda method and the necessity of producing cellulose at a lower price than that obtained by the bisulphite, have stimulated the technical experts to recover the lye and to use the sulphate of soda method which, in conjunction with the soda method, is to-day a process allowing of a larger production of pulp which has also the advantage of being easily bleached.

In the sulphate process the wood, after the bark has been removed, is reduced in chopping machines to chips of equal size. It then passes to a disintegrator, then to a sorting machine which separates the chips from twisted bits of wood. (The coarsest residues are used to make an inferior quality of pulp or used as fuel.)

The chips are then introduced into vertical or horizontal boilers, either fixed or rotating, heated by indirect or direct steam under a pressure varying from 6 to 11 atmospheres. The contents of the boilers are "blown" to diffusers, where lye continues the pulping process.

The washed pulp is led, under a current of water, into receptacles where it is stirred, and then pumped into purifiers (which keep back the knots and the bits which have not been submitted to boiling). Next it passes over sieves, where the other impurities (unpulped fibres, bark debris, etc.) that have escaped the purifiers are removed, and these are utilised to make a very coarse pulp.

After sieving, the pulp passes to the mixers for dilution, then to another stirring vat, and lastly to the centrifugal driers, which convert it into paste board very similar to the condition of mechanical pulp.

Pressing and drying eliminate a quantity of water up to amounts eighteen or nineteen times the weight of the dry fibre. In this way the paste becomes fit for transport.

The cellulose obtained has a brown colour and requires to be bleached before being used for certain purposes. The soda lye is recovered; the by-products used are recovered (methyl-alcohol, turpentine, liquid resin).

2) **The Bisulphite Method.** — This is most used at the present time, either because it is the most economical, or because, by means of this method of
treatment, the albuminoid and resinous matters are got rid of, and because, by the sulphurous gas liberated, a partial bleaching is effected.

The wood, after removal of the bark, pulping and sieving, is boiled in large cylindrical vessels lined with stoneware bricks (to prevent attack from the sulphurous anhydride), with the "acid", a solution of calcium bisulphite of a strength of 4% to 5% B. and containing sulphurous anhydride in a free state.

The lye for boiling is prepared as follows: the sulphurous gas obtained and chilled traverses, after passage through water, a tower made up of a series of chambers, one above the other, filled with limestone. The calcium sulphite thus formed and dissolved in water yields the liquid called "acid".

Boiling is carried out either with weak or strong acid according to the methods adopted or a combination of both. After boiling is over, pressure is lowered by letting off the steam and the excess of sulphurous anhydride in the bisulphite apparatus, and then the bisulphite solution is discharged. The woody matter passes with much water into great washing vessels, from which the pulp, after washing, passes through the operations described in the previous method.

The pulp goes to a mechanical sorter, to a press, and emerges with a content of about 18 per cent. of water. Bisulphite pulp can be used directly for the manufacture of ordinary white paper, but, for really good qualities, it is subjected to bleaching by chloride of lime.

The method of chlorination is based on the substitution of an atom of chlorine for the nearest hydrogen in the ketone or aldehyde groups contained in the non-cellulose part of the fibre in order to form a corresponding chloride. This, made soluble by an alkaline treatment, yields cellulose in a state of purity.

The process is as follows: the cellulose matter is treated slightly with soda in a closed vessel; after washing, it is subjected to the action of free chlorine. Hydrochloric acid is formed and reaction takes place with substitution between one atom of chlorine and one of hydrogen from the molecule of lignose or pectose.

Chlorination can be alternating (Cataldi process, in which use is made of electrolytic gaseous chlorine) or continuous (De Vains process, employing the hydrate of chlorine). The chlorinated matter is subjected to basic treatment either with a solution of caustic soda, caustic potash or sodium sulphite. Thereafter purification, bleaching, etc., are carried out.

To recover the soda from the wash liquor, the liquids are evaporated in special apparatus until the required concentration is reached; the juices are incinerated in continuous revolving furnaces by which a reddish product more or less mixed with cinders is obtained, called "salin". This, when broken up and dissolved in washers, yields a more or less weak solution containing sodium carbonate, etc. The liquids are filtered and heated in causticisers, where the liquid, mixed with lime, is converted into caustic soda with formation of carbonate of lime.

The filtered juice is sent to the receptacles for keeping the lye used for boiling.

A by-product in the manufacture of cellulose by the soda process is the Swedish resin ("Talloil"), which is obtained by cooling the black wash coming from the separation of the cellulose. The constitution of this resin is not well-defined, but it yields — on distillation, hydrogenation, or oxidation — several fatty acids.

Uses

Cellulose is used especially in the manufacture of paper, artificial silk, acetate of cellulose, nitrocellulose, varnishes or cellulose enamels, etc. (see these articles; see also the article "Varnish and Lacquer Manufacture ").

The by-products obtained from the washing are used in the manufacture of furfurol, bakelite, etc.

Dangers

Injuries to the health of the workers engaged in this industry are not numerous. There are the effects of dust (wood, vegetable fibres), and of the gases used (chlorine, sulphur dioxide, etc.) or given off during the various processes and getting into the atmosphere from leaks in pipes or apparatus that is not airtight. These risks, however, are very slight when the installations are well made and well maintained. In the department for the production of sulphurous anhydride, the emanations are very unpleasant, although the workpeople easily become acclimatised to them.

The gas first causes cough and irritation of the mucous membranes; but these troubles disappear quickly. Only anaemic workpeople complain of gastric trouble and nausea (Beintker).
Humidity is a worse trouble, and particularly the damp heat prevailing in certain departments.

In 1913-1914, the Swedish Ministry of Labour instituted an enquiry into the hygienic and sanitary conditions in cellulose factories; it was conducted by a particularly competent inspector of factories and a medical man. The enquiry extended to 37 of the 84 factories existing in the country.

In general, the conditions were good as regards lighting and cubic space. In certain cases, however, the air was hot and damp, very suffocating; and, in others, there was, in addition, the action of dust and sulphurous vapour.

The number of persons employed in the factories visited was 1,138; 229 were found to suffer from latent pulmonary tuberculosis; and 20 cases of bronchitis were reported, while 6 workers showed albumen in the urine, and 31 suffered from rheumatism. Four men who had inhaled large quantities of sulphur dioxide gas had suffered from acute symptoms; one man had had several attacks of lead poisoning.

The works' surgeons attached to 27 factories stated that the health of the workmen coming into contact with cellulose was no worse than that of the rest of the population, and might even be rather better, because in this branch of industry the higher salaries would allow of better food and healthier housing.

The surgeons also said that some workmen were sensitive to the action of sulphur dioxide, complaining of respiratory distress, while others seemed to be completely refractory to it.

The enquiry showed that there was no special risk to health in the industry in question, provided the equipment was on modern principles.

The enquiry made by Beintker in Prussia also showed that, in general, the workmen remained in good health, even after many years' employment.

For further details, see the articles "Bleaching", "Rag Industry", and "Paper Mills".

Hygiene

The construction of the factory must correspond, in its details, with the conditions demanded by the special processes carried out in this industry.

Thus, the floors should be impermeable, having a slight fall, and ribbed so as to allow the water, so largely used in the manufacture, to run off quickly. Necessary precautions must be taken against excessive humidity, gaseous emanations, whether toxic or merely unpleasant, in the working of the wood, chopping the fibres (locally applied aspiration and ventilation for the removal of dust, prevention of accidents and fire), in work with lyes or involving exposure to sulphurous vapours, etc., which should be done in closed apparatus under a negative pressure. The furnaces for making the sulphur dioxide ought to be rationally installed, the vapours emitted should be condensed, and there should be complete absorption of those which escape condensation.

One of the most serious inconveniences in the manufacture of cellulose with sulphate arises from the disagreeable smell which is given off from the different organic combinations of sulphur (especially of mercaptan), produced in boiling. A factory producing 16.5 tons of cellulose per day sends into the atmosphere 4.5 kg. of mercaptan and 0.73 kg. of methyl sulphide.

The unpleasant smells are usually absorbed by wood or straw to which chlorine is added as an oxydiser. Such deodorisation allows the proportion of sodium sulphite to be increased in the manufacture, and consequently permits of the production of better qualities of cellulose.

At the same time, this method has been improved by using an apparatus based on the principle of a barometric condenser. The vapours reach the apparatus at the top where they come into contact, at various stages, with one or more atomisers. These allow of very intimate contact between the vapours and the water. The sulphurous gases are oxidised by the air and the unpleasant smell destroyed.

Another trouble — and a very serious one some years ago — is that of the residual waters, which damage the streams with the bisulphite wash and may give off sulphuretted hydrogen gas.

The recovery, however, of the by-products (ethyl and methyl alcohol, cumol, turpentine, lignosol, tanning extracts, charbon de sulftte, etc.) has made these waters less injurious today.

A method proposed by Kumpfmiller and Philipp, in operation in a German cellulose factory working the bisulphite process, concentrates the wash waters under a vacuum until they are of a syrupy consistence and, on addition of certain chemicals, obtains tanning extracts which, however, cannot be used as such. Although this method does not solve the question completely,
it allows of a practical solution in several particular cases.

As an example of what can be made out of the wash waters, Lehmann has shown that nearly 80 grm. of solid substances contained in them, 4.5 are of an organic nature. If they cannot be utilised as raw materials for the products indicated above, it is best to evaporate and then burn them. König is said to have proposed the use of the evaporated residue for manure. (See also article "Industrial Waste Waters".)

The "Gulf" malady (Haffkrankheit), which attacked fishermen in a gulf in East Prussia in 1924, is said to have been caused in all probability by arsenic contained in the residual waters from a cellulose factory (see article "Arsenic").

**LEGISLATION**

In Finland Regulations for factories using the bisulphite process, dated 30 December 1924, and others for factories using the sulphate process (of the same date) are in force.

The first Regulations require, among other things, that the temperature of the workrooms should not fall below 15° C. nor exceed 20° C. during working hours, so long as technical conditions and the nature of work allow it; that efficient means should be taken to remove steam, gases, injurious vapours, and dust from the workrooms in order to prevent them getting into the air of other workrooms; that warmed air should enter the workrooms in cold weather; that piping, ducts, boilers, sulphur furnaces, reservoirs, and receptacles generally should be quite airtight and provided with the necessary safety devices; that efficient measures should be taken in the manufacture and preservation of the chemical products and by-products (sulphur dioxide, chlorine, inflammable and toxic volatile liquids, etc.); that preventive measures be taken against the risk of poisoning and fire in the manufacture of methyl alcohol, cumol, furfuro1, etc., as well as special measures in stripping the bark (accident and fire prevention), for work at the boilers, preparation of acids, distillation, etc. The Regulations also prescribe welfare arrangements and personal hygiene (spittoons, washing accommodation, working clothes, etc.), first-aid work for children and young persons, etc.

The Regulations for the sulphate process prescribe practically the same provisions. They require a further point, however: namely, that the manufacture and preservation of the products and by-products shall not be carried on except in a part of the factory specially constructed for the purpose; that the gases, vapours, and inflammable liquids, volatile or toxic, shall not be treated in reservoirs or receptacles open to the interior of the workrooms properly so called.

The uncondensed gases coming off when the gases are discharged, in extinguishing a furnace, should not be allowed to pass directly into the outside air, or into streams, or into rooms occupied by workmen, or into the immediate vicinity of the factory, but should be led to a chimney. The Regulations require special measures for the residuary wash waters, as well as for vapours and gases containing alcohol or oils to be kept or eventually dissociated.

Finally, another Order, dated 30 December 1924, has dealt with warehouses for the by-products of sulphate of cellulose factories. Detailed measures are laid down for emptying, cleaning, and scouring condensers, reservoirs, receptacles (the workpeople must not go inside to carry out these operations); for the purification of turpentine; for the use of sulphuric acid in the cleaning of certain receptacles (danger of boiling over or explosive reaction); of certain receptacles containing alcohol and intended for the manufacture of methyl alcohol; in the rectification of turpentine, etc.; in the handling of soap eliminated from the wash water in the manufacture of sulphate of cellulose, for the manufacture of liquid resin, etc. A supply of masks and breathing apparatus is required for certain processes, etc.

Norway excludes young persons under eighteen years of age from cellulose factories. See also the article "Paper Mills".

**BIBLIOGRAPHY**


Mr. Aksel Atterbom and Prof. Wirgin (Sweden).

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**Cements**


Cements are substances analogous to lime (see that article) which, when mixed with water or immersed under water, set...

1 It should be remembered that under the name "cements" other materials are spoken of, such as: mixtures of fatty matters, resins. magnesia, zinc, oxide, fine sand, etc. These are really pastes, or putties, or a kind of "Solvents", and are used for repairing broken porcelain, glass, etc. It should be borne in mind that several of them contain white lead, litharge, or red lead.
CEMENTS

in such a way as to acquire the hard consistency of stone. They are, however, made from substances containing more clay than lime, so that after burning they contain no more quicklime but components of lime and silica. Their setting, which is much more rapid than that of hydraulic lime, which takes place with the disengagement of heat, is due to the formation of a double silicate of aluminium and calcium or of a silicate and an aluminite of calcium.

The chief characters of cements are: their density, the time they take in setting [which can vary from a few minutes (quick setting cements) to more than an hour (slow setting cements)], their resistance and the consistency of their volume, the relative proportions of the constituents (lime, silica, alumina), the methods of burning and preparation which determine their more or less great hydraulicity and quickness in setting.

Cements take the form of very fine powder, generally of a grey colour inclining to green, and are put on the market in sacks weighing 50 kg. or in barrels of 100-250 kg. (for transport to a distance and for export).

INDUSTRIAL PROCESSES

These vary according to the kind of cement.

(1) Portland cement, the commonest, is a cement which sets slowly, of which the raw materials consist of lime, clay, and silica. Its manufacture varies with the country of origin, but natural Portland is obtained by burning directly a clayey marl. In Great Britain, where there is much chalk, this is used with other substances containing silica or alumina. Artificial Portland cement is made by mixing in suitable proportions marl, lime, and clay. Its composition generally falls within the following limits: lime, 57 to 67 per cent.; silica anhydride, 19 to 28 per cent.; alumina, 4 to 10 per cent.; ferric oxide, 2 to 4 per cent.; magnesia, 3 per cent.; alkalis, 0.2 to 3 per cent.; sulphuric anhydride, 0.2 to 1 per cent.

The raw materials are crushed between fluted rollers, then pulverised by grindstones or smooth rollers, or in crushing machines, which are of two types: quick running mills (in which the crushing is effected by steel balls or flint pebbles driven by centrifugal force against the metal walls of the apparatus) or by slow running mills (cylinders revolving round their horizontal axis and also containing steel balls or pebbles but acting only by their weight). Some of these apparatus are not completely closed, so that the dust coming from them is a danger for the workers.

Mixing is done either by a wet or dry method.

In the "wet method" the mixture is placed in tanks of water provided with stirrers. The resulting clear boiled slurry passes first into dosing tanks, then into settling tanks, which allow the paste to be recovered when the water is got rid of by decanting. The slurry goes directly into rotatory kilns; but in other types of kilns (continuous kilns) it has first to be made into bricks (by drying, passage through a perforated plate, cutting into length, and drying in a drying tunnel).

The "dry method" is used when the very hard raw materials must first be completely pulverised. They are then placed in rotating cylinders (provided inside with paddles for ensuring intimate mixture) or they circulate in a contrary direction to the hot gases. The mass is then made into bricks by compression in special brick-making machinery.

Burning is done at 1,400° C.; the lime reacts on the clay and forms aluminate and silicate of lime. The mass begins to vitrify and forms "clinkers." Hard pieces of a greenish-brown colour.

Among the many kinds of kilns, the commonest are the continuous kilns, comprising those with a short flame, similar to those used for lime (Aalborg or Schneider kiln), or automatic kilns (Maenstaedt type).

The placing of the bricks in the furnace is often done mechanically by means of travelling bands, automatically closing hoppers, etc., the Hofmann kiln similar to that used in the manufacture of pottery; the Dietzsch, commonly used, is a kind of chimney the width of which increases from above downwards and provided with openings which allow the vitrified portions sticking to the walls to be detached by means of tools; firing is effected half way up the kiln. Rotatory kilns are by far the most used at the present time. This type consists of a great steel cylinder, 40 to 80 metres long and 2 to 3 metres in diameter, lying horizontally at a slight inclination and heated by coal dust, mazout, or gas.

The slurry to be burnt passes directly into the uppermost end of the kiln and, as a result of the rotary movement, slowly moves down the slope to the lower end. In its course it meets with the hot gases traversing the cylinder in

1 Sometimes the bricks are made with slaked and sifted lime, mixed with a quick-setting cement into a double burning or Schneider kiln, which slow the paste to be recovered when the water is got rid of by decanting. The slurry goes directly into rotatory kilns; but in other types of kilns (continuous kilns) it has first to be made into bricks (by drying, passage through a perforated plate, cutting into length, and drying in a drying tunnel).
the opposite facing, by which it is first dried and then burnt.

On removing from the kiln the lumps are sorted to remove those that have not been completely burnt. Travertine and those that have been over burnt are rejected. Those which have received the desired amount of burning are kept, and all the lumps before being crushed and mixed are powdered. The powdered lumps are carried to a point where they are obtained, and, being ground with a screen 200 mesh per square centimetre, a residue from a sieve of 400 mesh is the square centimetre of more than 0.1 per cent. Pulverisation is intended by crushing and mixing with hydraulic lime the first-pavement residue obtained from the setting of heavy cases, because the cement is most in this case, 23 to 24 per cent., and water, and consequently one of the most hydraulic.

2. The slag of blast furnaces composed of sheets of lime and a small amount of basic cement is also used to manufacture cement, by exposing the hot furnace the slag is received into water, where it solidifies in the form of granulated stone. It is ground, sieved, and mixed either with lime in revolving cylinders.
off contain sulphurous anhydride. After having been collected in dust chambers, these gases are sent to the sulphuric acid factory, where they are treated by the lead chamber process or by the contact process.

(5) Pozzuolana, i.e. cement of volcanic origin, is analogous to cement from its composition, but it is very poor in lime. Artificial pozzuolanic cements are obtained by burning and crushing natural clays. Mixed with lime these natural or artificial products yield very quick-setting cements.

(6) Among the other kinds of cements may be cited mixed cements, a mixture of the non-pulverulent residue obtained when hydraulic lime is slaked with natural cements, or Portland cement with hydraulic lime; magnesian cements, prepared by starting from calcareous dolomites and used in submarine construction work; Scott’s cements, a mixture of lime and roasted gypsum; aluminous cements, obtained by fusion in the electric furnace or in a water-jacket of a mixture of bauxite and chalk, or of bauxite and lime (called also “fused cement”, “electric cement”), etc.

**USES**

Natural Portland cement is used for the manufacture of moulds, drain pipes, facings, etc., for building of every kind, submarine work, etc.

All the other cements are used for constructional purposes mixed with sand or gravel, and for making mortar, concrete, and reinforced concrete.

**Mortar** is a pasty material, drying rapidly in the air, obtained by mixing cement (or hydraulic lime) and sand, and then slaking with water. **Concrete** is a mixture of mortar and broken stones (about the size of pebbles on a road). **Reinforced concrete** is a mortar of slow-setting cement around a skeleton of iron (trellis or grill made of interlacing bands). They serve for the construction and utilisation of reinforced concrete, which every day becomes more and more widely used.

**Sources of Injury**

**In the Course of Manufacture**

There is, above all, the heat, which in the proximity of the continuous kilns reaches a temperature of 40-48° C. (from 18° to 25° C. near the rotatory furnaces), the outside temperature being 10° C.; then there are the draughts and poisonous gases given off in the course of manufacture from the coal used. Analysis made in a Russian factory gave an average of 0.0065 cubic metre of sulphuretted hydrogen gas and sulphuric hydride and 0.072 cubic metre of sulphurous anhydride per cubic metre of air.

The principal danger, however, comes from the dusts given off either by the raw materials when they are broken up or from sifting, mixing, or from the final product, cement.

Seen under the microscope, the coarse cement dust consists (according to Koelsch) of rounded particles of about 4 to 5 microns, the dust of finished cement consisting of larger hexagonal grains of 10 to 12 microns. The quantities of dust contained in a cubic metre of air in cement factories varies from 55 to 1,720 mg., with an average of 87 to 1,920 mg. per cubic metre in old factories, and 55 to 450 mg. in more modern factories, in which evidently the quantities of dust were less. Koelsch gives the following figures: removal from the annular kilns for burning the chalk, 155 mg.; sack packing rooms, 353-685 mg.; barrel packing...
rooms, 1,176-1,720 mg. Similarly, Ahrens found a content of 130 mg. of dust when the crushing apparatus was not working and 224 when it was.

The rotatory kilns produce enormous quantities of dust (up to several tons a day), which are drawn away in the gases and may cause serious injury to persons in the vicinity of the factory. The dusty processes are many; removal from the kilns; turning and lifting the material; charging the wheelbarrows; grinding, sifting, transport, bagging, and packing in barrels. The dust created in the course of grinding and sifting is the most dangerous because it is the finest.

**In Use**

The damage is due to the cement dust (see Uses, page 388).

The caustic action on the skin and mucous membranes from the cement dust is due to its hygroscopic property. It is explained by its composition: lime dust is due to its hygroscopic property. It is explained by its composition: lime, 62 to 65 per cent.; caustic lime, and silicic acid. Besides this chemical action it sets up a mechanical irritant action.

**Statistics**

Workers in cement factories show a pathology such as is common to the majority of workmen: wounds, intestinal troubles (especially constipation), rheumatism, boils, respiratory affections, bronchitis, etc., poisoning from fumes, etc.

While in Bavaria the morbidity was not higher than the general average, that published by the Sickness Insurance Society of Leipzig showed a high rate among cement mixers and hodmen: 1,338 sick days per 100 members.

According to Koelsch and other German writers, catarhal and respiratory affections constituted 30 to 40 per cent. of all the maladies from which cement workers suffer.

Other figures supplied by the reports of the Prussian factory inspectors (1911) and relating to 25,000 workmen show the following figures:

<table>
<thead>
<tr>
<th>Year</th>
<th>Cases of sickness</th>
<th>Number of sick days</th>
<th>Diseases</th>
<th>Fatal cases</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per 100 workmen</td>
<td>of the respiratory</td>
<td>of the lungs</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>tract</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cases</td>
<td>Days</td>
<td>Cases</td>
</tr>
<tr>
<td>1908</td>
<td>37.5</td>
<td>448</td>
<td>4.7</td>
<td>92</td>
</tr>
<tr>
<td>1909</td>
<td>30.8</td>
<td>469</td>
<td>5.0</td>
<td>90</td>
</tr>
<tr>
<td>1910</td>
<td>33.2</td>
<td>508</td>
<td>4.2</td>
<td>79</td>
</tr>
</tbody>
</table>

In the United States, according to statistics of Hofmann, 47 per cent. of cement workers die of respiratory diseases, tuberculosis representing 19.3 per cent.

An enquiry was conducted recently (1927-1928) by the Federal Service for Public Health in a large Portland cement factory, one of the most dusty in the industry, with a view to ascertaining the injuries due to cement dust. All data regarding absences, cause of illness, and quantities of dust in suspension in the air in the various workrooms were carefully collected. The workers were also medically examined, including radioscopic and, where necessary, radiographic examination.

The enquiry proved that the dust raised in the course of industrial operations in the factory does not predispose workers either to tuberculosis or to pneumonia. On the other hand, workers presented a high rate for diseases of the upper respiratory passages consisting chiefly of colds, acute bronchitis, pharyngitis and tonsilitis, as well as cases of influenza and grippe. Cases of the above diseases sufficiently serious to involve absences of two consecutive days or more were met with amongst workers in the most dusty departments amounting to about 16 per cent. more than in the case of workers in departments where relatively less dust was produced. Lime dust seems to be slightly more harmful than that of cement.

Work in the open air, such as that of stoneworkers, exposes the system to dis-
cases of the upper respiratory organs to a much greater extent than in the case of indoor exposure to cement dust. In the open-air operations in a cement factory the workers presented a higher percentage for rheumatismal affections. An enquiry revealed the fact that this work also involves exposure to certain skin diseases, to conjunctivitis and to ear affections (deafness). When the quantity of dust does not exceed about 10 million particles per cubic foot of air, it is doubtful whether the above-mentioned diseases occur with an incidence which exceeds the average.

For Italy, see article "Lime".

An enquiry made in 1925 in Russia in the cement factory of Erinsk over a period of two years among the furnace workers revealed the following maladies:

<table>
<thead>
<tr>
<th>Disease</th>
<th>Number of cases</th>
<th>Number of cases per 100 workmen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Per cent.</td>
</tr>
<tr>
<td>Bucal cavity</td>
<td>427</td>
<td>20.0</td>
</tr>
<tr>
<td>Respiratory tract</td>
<td>413</td>
<td>19.7</td>
</tr>
<tr>
<td>Skin and subcutaneous</td>
<td>374</td>
<td>18.2</td>
</tr>
<tr>
<td>Acute diseases of the</td>
<td>368</td>
<td>17.9</td>
</tr>
<tr>
<td>digestive system</td>
<td>187</td>
<td>8.9</td>
</tr>
<tr>
<td>Eyes</td>
<td>173</td>
<td>8.0</td>
</tr>
<tr>
<td>Blood</td>
<td>161</td>
<td>7.3</td>
</tr>
<tr>
<td>Bones, muscles, vessels</td>
<td>2,103</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Another enquiry made in 1927 relating to 1,116 cement workers showed the great frequency of atrophic rhinitis and polypi, as well as of purulent otitis. The cement dust, which "rises" readily, dispersed itself throughout the factory and especially in the grinding workroom, where analysis of the air yielded 133 to 504 mg. per cubic metre.

In Switzerland the lesions set up by cement notified to the National Accident Office, numbered 3 in 1919; 4 in 1920; 18 in 1921; 24 in 1922; 40 in 1923; and 54 in 1924.

As regards mortality, the enquiry of Koelsch showed an average rate (over ten years) of 0.62 per 100 workmen, as compared with one of 1.67 for the male population generally. The mortality from tuberculosis was, in Bavaria, 0.22 per 100 living (in 1907) as contrasted with 0.99 for the male population.

Authorities agree in laying stress on the slight frequency of tuberculosis and the rather low rate from respiratory diseases, which seem to be contrary to what one would expect from the enormous quantities of dust present in the atmosphere of the factories. Certainly, slight cases of bronchitis and asthmas escape report, but the small number of cases of tuberculosis may partly find an explanation in the chemical constitution of cement dust. This is composed of lime and siliceous acid — substances which are of some use in the treatment of tuberculosis, calcium having the property of increasing phagocytes, and siliceous acid helping to increase the growth of connective tissue, which favours the healing of tuberculous foci. According to Pesenti, cement dust is said to arrest the development of tuberculosis.

**Pathology**

Besides the maladies due to the high temperatures, the brusque changes in temperature and strain, and fatigue from kilnmen especially suffer (rheumatism, neuralgia, respiratory and cardiac diseases, etc.), the effect of the industry shows itself especially in mechanical and chemical action on the skin and mucous membranes.

The various forms of dermatitis, known under the name of "cement itch", commences with a fine papillary eruption, accompanied by intense pruritis, which increases with heat especially when in bed. Martial, who has described 78 cases, and Ascher, who has studied several, are of opinion that the lesion starts from excoriations of the skin, and that in appearance it resembles scabies very closely. An enquiry by Berger and Helwer (1892-1899) found it present in 10 per cent. of cement workers. The dermatitis is localised preferably on the hands and fingers (especially in the interdigital spaces) and over the joints, but in the absence of precautions or from other reasons it may extend to other parts of the body: thorax, axilla, forearm, elbow, face (infra orbital region, etc.). Then the papules get rubbed and covered with a crust which, when it falls off, leaves the skin raw. Sometimes there is oedema of the hands.

In this state the lesions will rapidly heal under appropriate treatment; but if the patient does not cease from exposure to the action of the dust the eruption gradually becomes eczematous with formation of crusts, and is accompanied by an intense pruritis involving at times constitutional symptoms such as sleeplessness, etc. If the patient does not give up his work quickly or recommences it before the first attack has been completely healed, the lesions, at that time limited to the superficial layers of the skin, penetrate down to the chorion and then give place to thickenings and cicatricial infiltrations of the whole of the skin, to such an extent that they appear as islets of skin of a thickened character and covered with vesicles, pustules, and rhagades. This is sometimes accom-
panied by fever, especially when the pustules or vesicles are developing. In all chronic eczemas, the lesion extends to the ears and eyebrows, tending to give a sad and set expression to the patient's face. If the malady is not arrested in time the development leads to a chronic thickening of the whole of the skin.

Cement itch may assume numerous forms according to its localisation. Thus among porters carrying sacks of cement, Pappanti-Pelletier has described a dermatitis situated especially on the scapular and clavicular region of the nape of the neck, but able also to spread to all parts coming into contact with the cement sacks. This dermatitis is characterised at its first stage by widespread hyperaemia of the epidermis, with slight desquamation and infiltration of the follicles. In the second stage of development, which lasts longer, all the follicles of the affected region become hypertrophied and stand out in relief above the interfollicular parts, giving the skin a "goose skin" appearance. The dryness of the skin is due to the absence of sweat and the alteration of the functions (secretion) of the sebaceous glands; the red colour of the skin is due to hypertrophy of the follicles induced by a thickening of the horny layer and retention of the sebaceous products. In the third stage, produced rather late, suppuration of the papules takes place and uniform pustules. Gross has described a case of necrosis of the skin localised to one of the legs; Neugebauer has seen several cases of eczema and even of superficial ulceration localised on the hands.

In the industry of modelling with cement other modifications of the skin have been described: the epidermis of the fingers whitens very rapidly, becomes softened, wears away literally visibly, and becomes at length the seat of minute, very painful ulcers attributed (Baudouin) to grains of silica acting like a raspat. On the other hand, the rapid alteration of the epidermal cells is explained by the caustic action of the lime present in the cement.

Among the lesions of the mucous membranes mention should be made of that of the nose: irritation, sometimes painful ulceration, which bleeds easily, and even perforation of the septum. Of 600 workmen examined by Koelsch, 17.3 per cent. had inflammation of the turbinals, 9.3 per cent. perforation, 1.7 per cent. perforation of the septum. One-third of these examined had, therefore, more or less severe lesions of the nasal mucous membrane. The presence of rhinoliths is rare. They are due to:

collections of cement dust forming calcull of varying size. Koelsch saw one weighing 0.75 grm. and measuring 34 x 15 x 4 mm. in a man who had worked for ten years. Betz found them in 7 to 10 per cent. of the men. Jurass in 1 per cent. only. (See above for the Russian data.)

Diffuse conjunctivitis, quite definite, sometimes occurs and necrosis at the points of the conjunctiva where the cement dust has alighted. Healing, when it occurs, does so with adhesions and serious functional troubles. Damage to the cornea is more serious. While in slight cases this is only superficial, showing itself as a speck of whitish colour like ground glass or porcelain, cicatisation generally leads to an indelible corneal opacity due to the organic combination of the lime with the albuminoids of the tissue. In serious cases the parts affected spherulate and cause not only reduction of sight but also sometimes perforation of the eyeball and loss of the eye. The cicatisation takes place with expectation of the eyelids—in or ectropion, trichiasis, etc. Of the 600 men examined by Koelsch, 12 per cent. had conjunctivitis.

In the mouth the cement particles may cause very small ulcers, but always visible to the naked eye.
According to Legge, cement dust affects the upper air passages, leaving the lungs unaffected. As a matter of fact, the respiratory affections present nothing specific; tuberculosis is not frequent. Occasionally broncholiths have been found in the large bronchi and even incrustations of the mucous membrane. (See also article "Lime").

A blood test made amongst cement workers by Saleck (1927) provided the following results: no punctate basophilia as in cases of lead poisoning; increase in the number of polychromat red cells, and in the case of a limited number of workers, red cells with fine and very fine granulations. These modifications of the blood were not accompanied by cutaneous lesions which would obviously have explained the modifications of the red cells noted by Saleck.

HYGIENE

The kilns should be arranged so that they are away from main roads and dwelling houses. The openings should be on the sides away from the public road. A stone or brick wall to act as a screen should be sufficiently high to prevent the glow of the kilns from being seen. The chimney stack should be very high to prevent the smoke from incommoding the neighbourhood. Fuel giving rise to unpleasant or unhealthy emanations should be avoided. Fuliginous gas should be burnt. Steps should be taken to afford protection from the radiant heat and smoke; from the danger of asphyxiation (avoid every pit or passage unprovided with an exit where toxic or asphyxiating gases can collect) or of fire (the store of fuel should be isolated from the hearth of the furnaces), metal gauze should be applied over the outlet of the chimneys; the kilns should be isolated, etc. All adequate measures should be adopted to diminish or suppress useless noise and vibration. A good system of ventilation should be installed, either general or locally applied, to remove the dust.

The water used should undergo decantation before being turned into the sewer or stream.

Excellent technical methods are now available for capturing and removing the dust, for ridding the smoke of dust (see article "Dusts, Fumes and Smoke"). The processes of breaking, grinding, sifting, sieving, bagging and barrelling, etc., can be done in closed apparatus with exhaust device (transport and filling should be carried out by mechanical means: elevators, travelling belts, etc.). Bagging machinery now permits not only of the filling of the sacks, but the weighing and automatic tying of them. Completely closed metal receptacles, into which the bags to be filled are introduced and fixed to the feeding mouth, allow the dust to be removed as soon as the cement has passed from the silo to the sack, thanks to a slight negative pressure maintained in the inside of the receptacle.

The dust caught by the locally applied systems of ventilation is carried to depositing chambers or to cyclones where it is thrown down and recovered.

Most works also have installations for freeing the sacks of dust which are then repaired.

Good locally applied exhaust ventilation naturally diminishes the risk from dust to workmen. According to Wittgen, in a German factory this means has reduced the frequency of respiratory diseases by one-third in the space of five years; the number of sick days were reduced from 2,742 to 812. In another factory an adequate plant for the removal of dust reduced the morbidity from respiratory diseases from 9.3 to 3.3 per cent.

Cleanliness must be emphasised as an important factor in prophylaxis. The persons employed, therefore, should have suitable and sufficient means for personal hygiene (wash basins, douches, baths, overalls, etc.) placed at their disposition. A little ointment containing lanoline should be rubbed into the hands before and after work (pig's fat and rancid fats should be avoided); goggles should be worn and respirators consisting of a piece of linen over the mouth; work should be given up in case of dermatitis until a complete cure has been effected. The treatment of cement itch belongs to the practising physician.

LEGISLATION

Women are prohibited from employment in grinding and sieving cement in the Netherlands. Young persons of less than sixteen years are prohibited from crushing, grinding, sifting, bagging, as well as from grinding mills, unless the dust is removed by mechanical means, in Belgium and Spain; of less than eighteen years of age in France, the Netherlands and Norway when dust is discharged freely into the air of the workroom; female young persons of less than eighteen years of age in grinding and bagging in Quebec; boys of less than fifteen years in Italy, if dust is given off freely; women of less than twenty-one under the same conditions in Spain, Italy, etc.
Regulations in some countries require the necessary measures to be taken to prevent escape of dust in workplaces and of toxic gases from the kilns: in France the Decree of 1 October 1913 lays down requirements as to the use of quick-setting cement, and the Decree of 9 October 1913 indicates what hygiene precautions are to be adopted in the use of cement:

I. With a view to protecting the hands and arms and face, workmen are recommended to make use of means such as brassièrês, ointments suitable for counteracting the effect of cement, goggles for work done on platforms, etc. Employers are advised to place these means at the disposal of the persons employed.

II. Workmen are strongly urged to make use of the means for personal cleanliness (which the irritating action of cement makes particularly necessary) at the place of work; the means for doing this are placed at their disposition by the employers.

III. When a cement worker is affected by extensive irritation of the skin he should be medically examined as soon as possible.

In Norway the Royal Decree of 30 October 1919 lays down the hygienic measures in regard to cement factories. Eczema and dermatitis and ulceration of the buccal and nasal mucous membrane are compulsorily notifiable in the Netherlands; dermatitis from cement is so also in Japan and in those countries where specific maladies or injury due to irritant and caustic dusts and liquids are named.

BIBLIOGRAPHY


GAUSSNER, J., in Gigieno Truda, 1925, No. 5. Moscow. (In Russian.)


Fig. 99 is reproduced from a photograph kindly supplied by the Belgian Factory Inspectorate.

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Cerium

French: Cérium. — German: Cerium, Cer.
— Italian and Spanish: Cerio.

CHEMICAL PROPERTIES

Cerium — symbol Ce, atomic weight 140.92, and specific gravity 6.72 — belongs to a group of metals found in very rare kinds of earth. It is a metal, iron in colour, capable of being cut by a knife like lead, melts at 623° C. and oxidises in the atmosphere, becoming covered with a black coating.

Cerium forms two series of salts: cerous salts, obtained from the oxide Ce₂O₃, and ceric salts, obtained from the bixoxide CeO₂, which are yellow or brown in colour.

INDUSTRIAL PREPARATION

Metal cerium is obtained by electrolyzing chloride of molten cerium with a small quantity of chloride of potassium. The graphite anode is suspended vertically in the axis of the bath; the cathode traverses the bottom of the bath. The metal obtained only contains 50 per cent. of pure cerium, the great difficulty being in fact to obtain a pure cerium salt. Cerium is accompanied in all ores by the metals of its group, from which it is difficult to separate it; monazite (a phosphate of cerium and other rare earths, particularly of thorium), cerite (hydrated silicate of cerium, lanthanum and didymum, etc.), gadolinite and orthite (likewise complex silicates).

The ores are first heated with sulphuric acid in order to render the silica insoluble. It is later eliminated by filtration. Oxalic acid, which only precipitates rare earths, is added to the solution.

A separation may be continued according to various methods: elimination of the thorium by maceration of the oxalates in the ammonium oxalate; precipitation in the state of phosphate insoluble in dilute hydrochloric acid; rendering insoluble the sulphate of cerium in the state of a double salt by means of a solution of sulphate of sodium; fractionated precipitation of the metals by means of ammonia or by chromate of potassium; by heat treatment of the nitrates (the nitrates of the various rare earths present an unequal resistance to heat) and elimination by water of the salts not transformed into oxide, etc.

See article "Incandescent Mantles" for the method of treatment of monazite to obtain salts of thorium and cerium.

USES

Cerium, when rubbed with a file, gives rise to violent sparking, not being, however, sufficiently hard for use alone in the manufacture of lighters; ferro-cerium is used for this purpose (70 per cent. of cerium and 30 per cent. of iron). This is prepared by melting the cerium
under a layer of chloride of barium, in order to protect it against the action of the air, then introducing gradually the pure iron into the molten mass.

Nitrate of cerium is a constituent of the liquids used for impregnating incandescent mantles. It is in fact transformed by calcination into oxide of cerium, which possesses a lighting capacity of a high order (see article "Incandescent Mantles").

TOXIC ACTION

According to Löwý, the toxic action of this product is without importance from an industrial point of view. Cerium precipitates albumin solutions in concentrations of average intensity. It has an astringent and vasoconstrictive properties. It causes tissue necrosis, paralysis of the central nervous system and of the heart and diminishes blood pressure. Administration of products with a cerium basis causes dryness of the mouth and a diminution in the secretion of the sweat glands.

According to Löwenthal, the red corpuscles suffer injury by cerium similar to that due to lead. There should also be mentioned the action of cerium on the skin of workers who have to manipulate it.

Hara recently (1926) has studied the toxic action of this metal and its salts on animals: smooth and striated muscles, nervous system, etc. He found that it caused loss of appetite, intense thirst, loss of weight and falling out of hair, etc.

In the course of its extraction from chloride, for preparing the compounds in combination with iron, at present much utilised for lighters, there is an abundant liberation of chlorine, capable, where adequate precautions are not taken, of causing serious injury to the worker and to the residents in the neighbourhood.

***

Chemical Trades


From the scientific point of view, the term "chemical industries" ought only to be applied to industries the products of the manufacture of which are obtained from chemical reactions. These products then have a composition different from that of the original materials. In this respect the prototype of chemical industries might be taken to be such manufacture as that of sulphuric acid, soda, chromates, superphosphates, aniline, etc.

At the same time, common acceptance, legislation, and industrial statistics in different countries habitually envisage under the term "chemical industries" numerous other industries — often such as do not involve any chemical operation and frequently even have nothing to do with chemistry. This is the case, for example, with the manufacture of blacking, tallow melting, bleaching of wax, manufacture of mineral waters, etc.

It is impossible to make a complete picture of the characteristics and processes of work of the chemical trades, as they are very different and are being continually modified. It should be remarked that the number of products is extraordinarily great and is increasing daily.

Numerous chemical products, both the raw materials used in their manufacture as well as the intermediate substances and their residues, can either exert a caustic action or cause burns or skin affections, or have a toxic action or possess, finally, other properties injurious to health either immediately or gradually. Such substances are also made or handled in other branches of industry, but their number is always small. On the other hand, in different chemical undertakings their number is relatively high. It should be understood that this applies only to certain big industries and, in particular, to the manufacture of intermediate products and aniline colours, because the majority of the chemical industries are confined to the manufacture of a single product. Thus it is, for example, in the manufacture of soda, sulphuric acid, hydrofluoric acid, and superphosphates.

The manufacture or treatment of injurious or toxic substances is by no means necessarily accompanied by injury to the health of the workpeople. In almost all cases it is possible to avoid, or at least to diminish, the risks, thanks to adequate regulations and arrangements. Actual knowledge of the facts indicates that in general it is only certain recognised substances which are particularly dangerous. In the first rank of these must be placed those which act on the organism or undergo absorption without the victim being aware of it.

The majority of lead compounds come under this head: litharge, red and white lead, chromate of lead, etc. These substances are only slightly soluble and do not possess any taste; that is the reason
why particles of these substances can be absorbed by the respiratory or digestive tract without knowledge, and it explains why these substances so readily cause poisoning.

Acetate of lead is soluble, but has a pronounced and peculiar taste; hence it cannot be swallowed without knowledge, and consequently poisoning by it is rarely reported.

The very great danger from carbon monoxide and mercury vapour similarly resides in the fact that these bodies are without smell or taste.

The most dangerous substances are those which can be absorbed by the unbroken skin. Among these nitro- and amido-derivatives of the aromatic series should be mentioned, of which the chemical industry manufactures and treats large quantities. Manipulation of them in the different departments requires the greatest precautions. Contact with them under certain conditions can be attended with the gravest consequences. But obviously it is not easy to protect the workmen handling such substances against all contact. It is therefore easy to understand that the manufacture and treatment of these matters gave rise in the early days to numerous and severe cases of illness. Since their method of absorption has been better known, the manufacture and treatment has become so little attended with danger that illness rarely occurs unless repair work requires to be done or accidents to the plant or the like develop.

It is always highly dangerous to enter vats or apparatus containing substances injurious to health. Permission to enter them should only be allowed on condition that the greatest precautions will be adopted and after care and cleaning. The persons who enter first should have a rope round their waists; further, a mate should always be close by the apparatus as long as anyone is inside.

Various attempts have shown that it is as difficult to give an account of the raw materials, processes of manufacture, and products made in the chemical industry as it is to give an exact picture of the state of health of the workpeople. The conditions vary in the several branches of the industry and even in the different factories and different countries.

However, so far as the industry in Germany is concerned, it is possible to give a sufficiently accurate account by using the data supplied by the Federation of Chemical Industries. It comprises the average number of full-time workers employed during the periods 1908 to 1910 and 1924 to 1926; the proportion of accidents notified, accidents compensated, and fatal accidents to the total number, and, further, all the data separately for all the causes mentioned under the headings (a) to (f) above.

Table I shows that in the period 1908 to 1910, 490 accidents were due to substances and toxic gases which caused absence from work for more than three days (col. 17), of which 113 received compensation, and of which 47 were fatal (col. 18). The corresponding figures for 1924 to 1926 were: 1,041, 110 and 45.

Acids, alkalis, etc., caused in 1908-1910, 2,840 accidents (cols. 15 and 16), of which

1 During the first thirteen weeks the expenses incurred by illness are borne in Germany by the sickness insurance societies.
292 (6 fatal) received compensation. In the years 1924-1926, there were 3,983 accidents, of which 244 (9 fatal) received compensation. Of the total numbers of accidents (col. 3), about 14 per cent. were due to substances and toxic gases and about 93 to 74 per cent. to acids and alkalies.

The number of accidents calculated as having occurred per 1,000 workpeople employed (which is also given in the accompanying table) yields still more precise information than do crude figures. In 1908 to 1910 there were 56.7 accidents per 1,000 full-time workers (of which 8.3 (0.55 fatal) received compensation (cols. 9 and 4)). From 1924 to 1926 the corresponding figures were 59.4, 5.21, and 0.47, respectively.

In 1908-1910 substances and poisonous gases occasioned, per 1,000 workpeople, 0.73 accidents, of which 0.17 received compensation, and 0.07 were fatal; whereas the figures for 1924-1926 were 1.00 accidents, of which 0.30 received compensation and 0.04 were fatal. As is seen, the number of accidents due to substances and toxic gases was not very high; on the other hand, the proportion of fatal accidents is relatively great.

Table II, also drawn up from the data supplied by the Federation of Chemical Industries, gives the number of accidents for which compensation was paid, distributed according to the different branches of the chemical industry. The number of reported accidents is not known. At the same time the figures in cols. 7 to 18 of the main chemical industry (col. 2) and for the aniline and aniline colour industry (col. 3), that is, of “inflammable, hot, caustic and poisonous substances”. In consequence of insufficient data it has not been possible to subdivide them. Whatever may be the reason, the frequency of accidents due to these causes is less than that of acute intoxications due solely to toxic substances.

In studying table II it should be borne in mind that cols. 3 to 9 give the arithmetic mean for the years 1924 to 1926.

Leaving out of account the small branches of industry, the number of accidents caused by inflammable, hot, caustic and poisonous substances is 1.1 per 1,000 for the main chemical industry (col. 2) and for the aniline and aniline colour industry (col. 3), and 0.8 per 1,000 for chemical, pharmaceutical and photographic products (col. 3), that is, for the last group a figure less than that of acute intoxications.

The fatal cases mentioned in col. 9 deserve special mention because, on the basis of the statistics in table I (cols. 18 and 20), one can consider what the probability was of the (approximately) three-tenths of the fatal cases of the whole group (table II, col. 9) having been similarly caused by poisonous gases in the period 1924-1926.

If the figures arranged in proportion to 1,000 workmen (col. 9) are examined, leaving out of account the small groups of workpeople (Nos. 14, 15, 18 and 19) which, in view of their small number, do not give an exact idea of the conditions, it is seen they are highest for the main chemical industry (line 2, col. 9) and the industries of pharmaceutical and photographic products (line 3, col. 9), that is, 0.2 per 1,000. Next comes the coal tar industry with 0.18 per 1,000. For the aniline and aniline colour industry, the proportion of fatal accidents is 0.16 per 1,000, which is very small when compared with the chemical industry as a whole, except medicines and manufacture of indiarubber and mineral waters.

The last reports of the Federation of Chemical Industries furnish data which complete the above-mentioned statistics, because they contain similar information on the industrial diseases which are not due to acute intoxications. As a matter of fact, eleven industrial maladies were treated as accidents by Order of the Minister of Labour dated 12 May 1925. This Order required the companies to give compensation to persons incapacitated as the result of the diseases in question in the same way as though they had been accidents. Consequently the industrial disease cases had to be reported to the companies.

Table III, which is based on the reports made in the course of the year 1926, has been taken from the annual report of the Federation of Chemical Industries. In studying it attention must be given to the following facts:

(a) Account only is taken of the reports on occupational diseases mentioned in the Order as maladies for which compensation must be awarded.

(b) Col. 1 gives the total reports made by medical men, employers, or workpeople.

(c) As a rule, no examination or complementary proof has been attempted to determine if the reports were correct except for the cases mentioned in cols. 6 and 10 — col. 6 containing all the reports regarded as correct, and col. 10 those that were not regarded as being an industrial malady.

(d) So far as what is stated in cols. 2 to 5 is concerned, the need of determining whether or not they were compensable industrial diseases does not arise, because in those cases recovery of their capacity to work had taken place within the thirteen weeks. It is not stated whether there had been revision of the cases.

In examining table III, when comparing cols. 6 and 10 — see above paragraph (c) — it is apparent at once that the reports based on initial examination were very uncertain. While the control medical examination supported, in 68 reported cases of lead poisoning, the diagnosis that lead intoxication was present, in 60 cases this diagnosis was not upheld. The 3 diagnoses of phosphorous poisoning were erroneous. Similarly, 8 out of 9 cases of mercurial poisoning, 10
<table>
<thead>
<tr>
<th>Year</th>
<th>Number of full-time workers</th>
<th>Reported accidents due to inflammable, caustic and toxic substances</th>
<th>Cases compensated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Explosions from fire due to gas, petrol or alcohol</td>
<td>Cases notified</td>
</tr>
<tr>
<td>1</td>
<td>210,701</td>
<td>1,006 (120)</td>
<td>Cases notified</td>
</tr>
<tr>
<td>1908</td>
<td>1909</td>
<td>1,304 (96)</td>
<td>Cases notified</td>
</tr>
<tr>
<td>1910</td>
<td>230,446</td>
<td>1,770 (112)</td>
<td>Cases notified</td>
</tr>
<tr>
<td>1911</td>
<td>666,798</td>
<td>5,534 (368)</td>
<td>Cases notified</td>
</tr>
<tr>
<td></td>
<td>1,000</td>
<td>8.3 (0.55)</td>
<td>Cases notified</td>
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<tr>
<td>1924</td>
<td>300,390</td>
<td>1,477 (190)</td>
<td>Cases notified</td>
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<td>1925</td>
<td>374,714</td>
<td>2,193 (173)</td>
<td>Cases notified</td>
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<tr>
<td>1926</td>
<td>338,562</td>
<td>2,011 (156)</td>
<td>Cases notified</td>
</tr>
<tr>
<td>1927</td>
<td>1,877,886</td>
<td>5,500 (500)</td>
<td>Cases notified</td>
</tr>
<tr>
<td></td>
<td>1,000</td>
<td>5.21 (0.47)</td>
<td>Cases notified</td>
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</tbody>
</table>

The figures in brackets indicate total cases for which compensation was paid.
<table>
<thead>
<tr>
<th>Branches of industry</th>
<th>Number of works (average for 1924-1926)</th>
<th>Number of full-time workers (average for 1924-1926)</th>
<th>Number of accidents which compensation was paid (average for 1924-1926)</th>
<th>Number of accidents for which compensation was paid caused by explosives, inflammable, hot, caustic or poisonous substances or gases</th>
<th>Number of accidents which compensation was proved fatal</th>
<th>Total</th>
<th>Fatal cases</th>
<th>Total</th>
<th>Fatal cases</th>
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</thead>
<tbody>
<tr>
<td>1. Salt works</td>
<td>24</td>
<td>1,692</td>
<td>5</td>
<td>2.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>2. Main chemical industry</td>
<td>290</td>
<td>59,827</td>
<td>428</td>
<td>2.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>3. Other chemical, pharmaceutical and photographic products</td>
<td>1,896</td>
<td>80,473</td>
<td>373</td>
<td>1.0</td>
<td>0.3</td>
<td>65</td>
<td>0.9</td>
<td>13</td>
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<tr>
<td>4. Medicine</td>
<td>5,561</td>
<td>16,857</td>
<td>15</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5. Manufacture of colours, except coal tar colours</td>
<td>391</td>
<td>13,506</td>
<td>64</td>
<td>-</td>
<td>-</td>
<td>11</td>
<td>0.8</td>
<td>2</td>
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<tr>
<td>6. Manufacture of pencils, pastels and chalks</td>
<td>45</td>
<td>319</td>
<td>6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>7. Manufacture or aniline and aniline colours</td>
<td>19</td>
<td>38,729</td>
<td>250</td>
<td>-</td>
<td>-</td>
<td>43</td>
<td>6</td>
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<tr>
<td>8. Manufacture of other coal-tar derivatives</td>
<td>74</td>
<td>7,570</td>
<td>26</td>
<td>4</td>
<td>-</td>
<td>5</td>
<td>1.3</td>
<td></td>
<td></td>
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<tr>
<td>9. Manufacture of explosives</td>
<td>129</td>
<td>13,887</td>
<td>89</td>
<td>23</td>
<td>19</td>
<td>7</td>
<td>1.3</td>
<td></td>
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<tr>
<td>10. Manufacture of matches</td>
<td>79</td>
<td>5,714</td>
<td>25</td>
<td>1.7</td>
<td>1.7</td>
<td>3</td>
<td>0.3</td>
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<tr>
<td>11. Removal of night soil and disinfection</td>
<td>71</td>
<td>476</td>
<td>4</td>
<td>0.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>12. Manufacture of artificial manure</td>
<td>170</td>
<td>7,886</td>
<td>54</td>
<td>5.3</td>
<td>-</td>
<td>2</td>
<td>0.3</td>
<td></td>
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<tr>
<td>13. Knackers' yard work</td>
<td>221</td>
<td>599</td>
<td>8</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>14. Manufacture of wood charcoal, and extraction of wood-tar and soot</td>
<td>45</td>
<td>668</td>
<td>20</td>
<td>3</td>
<td>1</td>
<td>0.3</td>
<td>3</td>
<td>1.7</td>
<td>0.65</td>
</tr>
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</table>
TABLE II (continued)

<table>
<thead>
<tr>
<th>Branches of industry</th>
<th>Number of works (average for 1924-1926)</th>
<th>Number of full-time workers (average for 1924-1926)</th>
<th>Number of accidents for which compensation was paid (average for 1924-1926)</th>
<th>Number of accidents for which compensation was paid caused by</th>
<th>Total Fatal cases</th>
<th>Total Fatal cases</th>
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<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Extraction of resin and pitch</td>
<td>2</td>
<td>3 4 5</td>
<td>6 7 8</td>
<td>8 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Fat melting, manufacture of tallow candles, soap refining</td>
<td>26</td>
<td>10,000 87 3 13</td>
<td>5 8</td>
<td>8 0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. Manufacture of stearine and wax candles</td>
<td>159</td>
<td>3,924 14 0.8</td>
<td>8 0.3</td>
<td>0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. Coal-tar distillation, manufacture of mineral oil, gas, ether, etc.: paraffin candles; refining of mineral oils</td>
<td>105</td>
<td>6,233 47 5</td>
<td>6 2</td>
<td>2 0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. Melting whale oil; preparing lubricating oil for leather and coach building</td>
<td>201</td>
<td>2,177 10 2</td>
<td>3 1.3</td>
<td>1.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. Manufacture of ethereal oils and scents</td>
<td>275</td>
<td>6,875 16 0.7</td>
<td>2 0.3</td>
<td>0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21. Manufacture of resins, varnishes and mastics</td>
<td>1,152</td>
<td>18,000 52 2.3</td>
<td>6 1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22. Manufacture of felt and bituminous paper for roofing</td>
<td>181</td>
<td>2,853 26 5</td>
<td>5 0.7</td>
<td>0.7</td>
<td>2 0.3</td>
<td>2 0.3</td>
</tr>
<tr>
<td>23. India-rubber and gutta-percha manufacture</td>
<td>621</td>
<td>53,830 191</td>
<td>9 1.3</td>
<td>1.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24. Works for impregnating materials other than wood</td>
<td>34</td>
<td>272 21 0.3</td>
<td>2 0.3</td>
<td>0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25. Manufacture of artificial mineral waters</td>
<td>1,653</td>
<td>3,887 26 1.3</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>237,886 1,863 169.7</td>
<td>964.4 56.6</td>
<td>0.7 0.147</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE III

<table>
<thead>
<tr>
<th>Industrial poisonings and diseases</th>
<th>Number of industrial maladies reported in 1926</th>
<th>Cases settled without coming to a decision: duration of the malady</th>
<th>Number of cases decided as being industrial maladies</th>
<th>Cases which involved</th>
<th>Cases not recognised as industrial diseases</th>
<th>Cases not yet settled</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Less than 4 weeks</td>
<td>4-5 weeks</td>
<td>5-6 weeks</td>
<td>More than 6 weeks</td>
<td>Payment</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Cases due to lead and its compounds</td>
<td>534</td>
<td>147</td>
<td>53</td>
<td>35</td>
<td>166</td>
<td>68</td>
</tr>
<tr>
<td>Cases due to mercury and its compounds</td>
<td>9</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cases due to phosphorus</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cases due to arsenic and its compounds</td>
<td>20</td>
<td>8</td>
<td>6</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cases due to benzol and its monologues</td>
<td>12</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cases due to the nitro- and amido-derivatives of the aromatic series</td>
<td>27</td>
<td>4</td>
<td>7</td>
<td>-</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>Cases due to carbon bisulphide</td>
<td>46</td>
<td>8</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Cases of cancer of the skin due to soot, tar, paraffin, anthracene, pitch, and similar substances</td>
<td>6</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

out of 11 cases of benzol poisoning, and 30 out of 46 cases of poisoning by carbon bisulphide were wrong.

If acceptance were given to the opinion — which is certainly going too far — that the reports of cases of illness settled without complementary examination (those comprised in cols. 2 to 5) were all correct, the total number sent in in 1926 in the chemical industry would have been 521, of which 469 were cases of lead poisoning, 3 mercury poisoning, 12 arsenical poisoning, 2 benzol intoxication, 17 poisoning by nitro- and amido-derivatives of benzene (of which 1 was fatal), 16 carbon bisulphide poisoning, and 2 cases of soot, tar and anthracene cancer, etc. On the other hand, if half only — and this doubtless is much more likely — of the reports included in cols. 3 to 5 are correct, the number of industrial maladies would be only 298. As regards lead poisoning, a fairly large number of cases relate to paint and colour works: similarly, a large proportion of the cases of carbon bisulphide poisoning relate to the India-rubber industry. From this point of view, it would appear that the number of diseases for which compensation had to be paid in the chemical industry — taking this in its limited acceptation — was not very large. To the 521 or 298 industrial maladies there would still require to be added for the year 1926 (table I, col. 17) 398 acute cases of poisoning set up by gases and poisonous substances, that is, a total of 947, or 624 which involved incapacity from work for more than three days. According to table II, the number of workpeople employed in the chemical industries, leaving out of account medicines, rubber and aerated water factories, was 280,000. This makes 3 or 2.2 industrial maladies per 1,000 full-time workers. But these figures are only averages and have not great value for particular undertakings or branches of industry.

The statistics of the German sickness insurance societies comprise in general all cases of sickness which have caused incapacity for work of more than three days. Among the statistics of morbidity relating to the chemical industry in Germany, drawn up on the basis described, account should be had of those of Grandhomme in his work Die Fabriken der Farbewerke Meister Lucius und Brüning in sanitärer und sozialer Beleuchtung.
those of Leymann which appeared in *Concordia*, 1906, pp. 101-107, 114-124, and 131-136, and in *Concordia*, 1910, pp. 355 et seq., and lastly the valuable statistics of Curschmann in his annual reports of the Federation of Chemical Industries for the years 1909, 1910 and 1911.

Grandhomme, who included in his statistics all cases, even where they did not give rise to incapacity, found that in departments making sulphuric and nitric acid and intermediate products, aniline colours and anthracene, in the years 1893 to 1895, there were 15 cases of occupational disease per 1,000 workers, including the cases treated in consultations.

Leymann found in a factory for sulphuric, nitric and hydrochloric acid, organic in intermediate products, organic chlorine compounds, etc., 13 cases of poisoning per 1,000 workpeople, and in an aniline colour factory not preparing intermediate products 1.2 cases of poisoning per 1,000 workpeople. For the period 1909-1910 Curschmann found in the main chemical industry, omitting the manufacture of lead colours, 2.1 cases of poisoning per 1,000 workmen. These figures sensibly resemble those drawn up by the Federation of Chemical Industries, especially if consideration is given to the fact that in the material Curschmann dealt with the number of cases of lead poisoning was 18 per cent. only, while in the statistics mentioned above they numbered 30 or 50 per cent. of the cases.

Grandhomme's and Leymann's figures can be readily understood to yield higher figures than those of Curschmann because the manufacture of intermediate products, especially of nitro- and amido-derivatives of the aromatic series, readily give occasion for poisoning, at any rate during the years under review. Examining the data given, it is noticeable that in the chemical industry the number of industrial diseases involving incapacity for work for more than three days is relatively less than that of accidents with incapacity lasting more than three days. The figures in the case of 1,000 workers for industrial diseases are 2 to 3 as compared with 59.7 for accidents. Similarly, the total number of industrial diseases was small in comparison with the total sickness. In the years 1909 and 1910 Curschmann found 54.9 cases of sickness per 100 workmen per annum, of which 0.21 were professional intoxications, a proportion of 0.4 cases of occupational diseases per 100 cases of illness generally. Grandhomme's proportion was 1.63 per cent. and Leymann's 1.67 and 0.2 per cent.

To understand the figures it must be understood that: (a) they are the average and that conditions are very different in different branches of industry; (b) the figures do not include asphyxiating actions, burns or diseases of the skin; (c) the injurious action of the materials handled shows itself very often in an increase in the diseases of the digestive tract and other organs. Leymann's statistics bear on this point, but as they relate only to one factory and fixed conditions it is not fair to generalise from them.

The data presented above relate exclusively to the German chemical industry, which in general, and especially in the large works, possesses efficacious means for protecting the workpeople. Equally satisfactory statistics are not obtainable from other countries. As a matter of fact, the *Annual Report of the Chief Inspector of Factories in Great Britain* contains, it is true, statistics of great value, but they do not specify the chemical industry only.

In the State of New York the number of accidents in the chemical industry was, in 1925, only 3.8 per cent. of all industrial accidents. Compensation for accidents per 100 cases was as follows:

- Motors, transmission machinery: 5
- Transport installations, lifting hoists, lifts: 11
- Poisonous and caustic substances: 14
- Explosives, electricity, burns: 18
- Falls, shocks: 29
- Fall of objects: 6
- Transport of objects: 9
- Tools: 4
- Various causes: 4

In the U.S.S.R. Shapiro-Aronstamm visited, in 1925, 218 workmen of the Polewo chemical factory (sulphuric, hydrochloric, nitric acids, etc.): 100 of these workmen were occupied in processes of manufacture, 39 per cent. being from twenty to twenty-nine years of age, and 3.7 per cent. over fifty; 43 per cent. had worked in the trade for one to three years; 25 per cent. from three to ten years, and 9 per cent. for more than ten years.

Among the diseases reported were first and foremost those of the respiratory tract: 56 cases (25.7 per cent.) were early forms of tuberculosis; 21 (9.6 per cent.) were in the second stage. There followed, in order of frequency, diseases of the circulatory system (mainly functional lesions), neurasthenia, diseases of the eyes. Twelve per cent. of the workmen had suffered accidents with temporary incapacity, which reached 21.2 per cent. among the apprentices. Burns, especially of the hands, iron acids showed a relative value of 38.

In the same year, Pachomyczew studied the health of 2,318 workmen and salaried employees in eleven chemical works in Moscow (soap factories, scent, glue, colours, etc.). Here also respiratory diseases were the most frequent, especially in the groups working at a high temperature (60 per cent. of the men, 61.6 per cent. of the women), in the departments where gases were given off (sulphuric and sulphuric anhydride, hydrogen sulphide, chlorine, acid and nitrous vapours, etc., 46.8 per cent.), humid departments (56.4 per cent. of the men, 54.3 per cent. of the women), dusty sections (40.4 per cent. of the men, 18.9 per cent. of the women). Of the total in all sections, respiratory diseases figure with a relative value of 33 for men and 25 for women.

Diseases of the circulatory system showed a value of 23; those of the lymphatic system (adenitis) one of 46.2 per cent. for men and 11.5 per cent. for women in...
the glue factories, while the ratio was 6-8 for men and 2 for women in the other factories.

In the colour factories 26.5 per cent. of the men and 33.3 per cent. of the women showed diseases of the nervous system. They related mainly to persons engaged in making sulphur, azoic, and nitrated colours. In general the women were less affected by illness than the men; 7 to 20 per cent. of the workmen complained of muscular weakness; 18 to 35 per cent. were ill-nourished.

Schwarz, of Kazan, visited, in 1927, 2,400 workmen in the chemical factory at Bondshuga, where 804 workmen were engaged in chemical processes. Five per cent. only were from seventeen to twenty years of age; 1.3 were above sixty years.

Sickness was very high among the skilled workmen (25 per cent.), much less among the unskilled. He found especially cases of bronchitis, rhino-pharyngitis, myocarditis, varicose veins, diseases of the skin, flat feet, and conjunctivitis. Chlorine acne was not found, perhaps because the Weldon method was used.

In Switzerland the statistics of accidents relating to about 10,885 persons employed in the chemical industry during the period 1920-1921 gave 2,040 cases, of which 31 were fatal.

While transmission and other machinery, etc., accounted for 421 accidents (20.6 per cent. fatal), transport of loads by hand or machine were responsible for 479 cases (23.5 per cent.), falls of persons or of weights on them for 330 cases (16.2 per cent.), hot, caustic substances and explosives for 344 accidents (27.6 per cent.), and industrial diseases for 102 cases (5 per
Rust also collected about 900 cases, so that these or do not protect the eyes sufficiently. In these cases the goggles are awkward to wear and ducts have to be pressed, because in these accidents the protective goggles are not worn carefully for each individual, almost always prevents phylaxis is possible, and replies that in intervention.

describes the clinical picture, course and possible sequelae, and the data for diagnosis, for expectant treatment, and for intervention. The author asks if prophylaxis is possible, and replies that in the majority of cases it is; thus, the wearing of goggles, if carefully selected for each individual, almost always prevents accidents. Naturally, this precaution is not often applicable in departments where the temperature is very high, or the products have to be pressed, because in these cases the goggles are awkward to wear or do not protect the eyes sufficiently.

Egli collected 475 cases of poisoning and injury caused in the chemical industry — a number which later he raised to 742. Rust also collected about 900, so that these two experts analyse in their work a total of 1,600 cases.

Failure of attention and sometimes carelessness, it is interesting to observe, have been the cause of serious accidents, even to trained persons. Naturally, ignorance has been the cause among pupils from secondary and preparatory schools (experiential courses in chemistry). Cases of injury are numerous also among university students and assistants in institute. Ignorance, inhalation of toxic gases, etc. Many professors have been laid up with serious injuries due to accidents from the chemical substances used in their researches as, for instance, Durong injured in 1811 by chloride of nitrogen, Guttermann, Meyer, Pebal, Hantzsch, Ramberger, Cur-tius (by hydrobromic acid), Liebig, Peckmann (by diazo-methane), Bruhl, Net, Pictet, 'Scheele (by hydrocyanic acid), Standinger, L. Wohler (by the compounds of tellerium and cyanides), Will, etc. Fatal cases are also numerous, among which mention should be made of A. F. Gelen (1815, at Munich, from arsenic-related hydrogen gas), Britton (at Dublin from the same gas); C. Heumann (in 1894, after suffering for eleven years from the effects of the inhalation of chlorine vapour); G. Matzuske (from mine gases); the two young English assistants, C.U. and T.S., from mercury dimethyl, of which the toxicity is not yet known; etc.

This is the reason why (in France, for example) chemical engineers are also accepted for compensation from accidents and diseases of industrial origin.

The hygienic conditions of the chemical industry in Italy have been studied by Loriga and Legnelli in the report presented to the second conference of the International Association of Chemistry (Brussels, 1921). They brought out clearly the complex form under which the causes of danger present themselves in this industry. Certain substances which are formed during reactions, remain partly unknown because the analysis required to detect them requires too much time, too much research, and too much apparatus. In small works the director is more a manager than a qualified chemist. The difficulties in the way of studying the action of impurities and reactions are in this case even greater.

Hygiene

Hygiene has for its object the protection of the neighbourhood against the dangers and unpleasantness of industrial operations on the one hand, and, on the other, the protection of the workman himself against the agents which menace his health while at work. These dangers may be classed as follows: transmission of toxic fumes; emission of flames and particles set alight by furnaces and chimneys; danger of fire and explosion not only from explosives but also from gas, smoke and even dusts; deposit of smoke and soot coming from coal and wood furnaces; production of smoke which often becomes converted into clouds when combined with the dust; production of smells and disagreeable exhalations, diffusion of irritating and encrusting dusts; infiltration of irritating, corrosive and toxic gases; contamination of the soil, subsoil or surface by water, by substances used in dyeing or toxic substances or by substances setting up fermentation, polluting the atmosphere or contaminating the water in such a way that it becomes no longer palatable to man or animals, cannot be used for domestic needs or for industrial use and will not allow fish to live in it.

Legislation

Generally speaking, women are excluded from chemical factories. Young persons of less than fifteen years are excluded in Japan from operations bringing them into contact with a long series of products (prussic acid, cyanides, mineral acids, caustic soda, phenol, etc., and other caustic and poisonous substances and everywhere where emanations and vapours are given off: prussic acid, fluorine, aniline, or chrome from chlorinated their compounds or other analogous toxic substances); in the chemical industry in Poland; under sixteen years in France (distillation in the manufacture of petrol on a large scale, benzenes and hydrocarbons in distillation rooms and storehouses); young persons less than eighteen years in electro-chemical factories in Norway, etc. Statutory measures, therefore, for the prevention of injury in the chemical industry are of great importance. These measures have been carefully studied by experts in different countries...
and large works have derived great benefit from them. Among others, note should be taken of the measures drawn up by the Association of the German Chemical Industry for the prevention of fires, explosions and poisoning. In the prophylactic work much assistance has been given by the Association of Factory Surgeons in the chemical industry created in 1905. Great Britain, the United States, etc., have contributed much to this cause.

The German Association prepared the regulations for health and safety for nineteen groups of chemical industries. These regulations relate to the construction of the factories, the best arrangement of the various departments and apparatus, the lighting and heating, the installation of electric motors, general and localized ventilation, etc. Very detailed instructions are given also as to the capture, removal and neutralisation of poisonous gases, the precautions to prevent dust (risk of poisoning, fire and explosion), handling of caustic and irritating liquids, etc.

Special Measures. — These are numerous in Germany, Great Britain, etc., and are drawn up for several industries, such as matches, chromates, carbon bisulphide, india-rubber, tar, nitro- and amido-derivatives, mineral oils, explosives, etc. (see these articles).

These regulations provide for the suppression or minimising of all causes likely to cause collisions, concussion, accumulation of static electricity, heat, etc., arising from fire, explosion, etc., of the substances in question. The best means of installing heating, the placing of boilers, electrical motors, the piping for hot water, steam, etc., have especially been carefully thought out. Not less important are the measures to be adopted to minimise or prevent injury to the workpeople. Instructions relative to the risks run should be mentioned: exact knowledge of the means of protection, their use and objects; collaboration with the staff in the work of prophylaxis; placing at the disposal of the workmen all means of ensuring good personal hygiene; supervision to ensure that these are used; adequate medical supervision at the commencement of employment at periodic intervals, in the selection of workpeople, and advice as to the best way of employing them, with continuance of their training in health matters; adequate first aid provisions and instruction of the personnel in ambulance work (while awaiting the arrival of the doctor); posting up of placards and distribution of leaflets for propaganda. Health and safety precautions generally are laid down for different industries in Government Factories Act: aniline; nitro- and amido-derivatives; chromates; phosphorus; lead; carotting; arsenic; mercury; etc. At the same time there are general regulations applying to certain groups of the chemical industries. Thus, for example, in Germany, sections 16-25 of the Industrial Code deal with installation and alterations in chemical works; in Great Britain the Regulations of 11 July 1923 deal with the manufacture of chemical substances (manufacture or use of carbonates, chlorates, chromates, hydrates of potassium or sodium, iron, cobalt, nickel, arsenic, etc.; ammonia, mineral acids, organic compounds as well as their metallic or organic salts; compounds of cyanogen; electro-chemical industry; and other articles; hydrogen sulphide; chlorine for bleaching powder, distillation of tar, its use as well as the substances distilled, refining of shale oil, manufacture of nitrogen compounds, including explosives).

The Regulations lay down the requirements concerning every fixed receptacle: tank, vat, containing dangerous matter and uncovered, in such detail as to avoid every ordinary risk; locally applied, exhaust ventilation in certain processes for the removal of injurious vapours and dusts (lime, for example). The Regulations prescribe also the provision of breathing apparatus, of compressed oxygen, safety belts, and even the precautions to be taken before entering places (tanks, boilers, etc., where there might be risk of the accumulation of inflammable gases. Measures are laid down for the entire immersion with cold water of persons splashed by corrosive liquids or strong acids; installation of cloakrooms and first aid boxes; medical supervision and measures for personal cleanliness. A portion of the Regulations is limited to parts of works where use is made of caustic pots, or where chlorate or bleaching powder is made; where tar is distilled, or nitro- and amido-derivatives are made, or shale oil refined, etc.

In México (State of Jalisco), sections 205 et seq. of Decree No. 2308 (13 August 1923) deal with the measures to be taken in industries using chemical substances. In Norway the Royal Decree of 20 September 1920 deals with the hygienic conditions in the electro-chemical industry; that of 29 June 1923 regulates the factories making sulphuric and nitric acid, ammonium nitrate without making use of electricity.

In U.S.S.R. the mineral salt and acid factories are governed by the Regulations of 10 April 1922.

So far as concerns the work of women and children, reference is made to the different chemical products, the diseases to be notified and those for which compensation is to be awarded.

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The period from twelve to sixteen or eighteen years of age, when occupational work begins, generally includes the most active stages of bodily development as regards growth and puberty.

The question is all the more important since children and young persons — and, indeed, women as well — are chiefly occupied in industries where the hygienic or special conditions are the least favourable for work.

Whilst it is true that legislation tends more and more to limit the employment of children in industry, so that in Germany, for instance, only 10,271 children below the age of fourteen years are to-day being employed, on the other hand it is none the less true that children are too often employed on domestic work under hygienic conditions certainly less favourable than those found in large factories.

**Physiological Facts**

The phases and laws of normal growth are summarised in an important report presented by Pende to the Italian Congress on Internal Medicine in 1927. This expert agrees with Godin that from the clinical point of view the first period of growth is from one to four years; that is the period of the *turger primus* of the ancients. The second period, that of "the second childhood", is from four to six and a half years; that period includes such important changes that Pende calls it the period of "small puberty", commonly called *proceritas prima*.

The third period is from six and a half years to the commencement of puberty (fourteen and a half years for girls, fifteen and a half years for boys). Pende divides this period into two parts; during the last phase, from thirteen and a half to fifteen and a half years, which may be called more strictly prepubertal, some important evolutionary changes are taking place, to wit, changes which easily pass into the realm of illness.

The fourth period is that of puberty, properly so called, which lasts two years: in girls from fourteen and a half to sixteen and a half years and in boys from fifteen to seventeen and a half years.

The fifth period is the inter-puberty-nubility period of Godin, which extends from the termination of puberty to the period of nubility (twenty-one and a half years of age for women, and twenty-three and a half for men); it is the period of so-called youth, of sexual maturity, but it is not that of body maturity. This is why German experts fix the cessation of growth between ages of twenty-five and twenty-eight.

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**Children and Young Persons**

**Employment of**


The movement in favour of legal protection for children and young persons is of comparatively recent date, for it is well known that in the early stages of industrialism no one troubled either about age on admission to factories or the conditions under which work was carried on.

It suffices to recall here that in the case of Great Britain these conditions were so serious, that to-day no objection is raised to the principle of stricter intervention than has been hitherto adopted by certain countries.

The movement then spread to the continent and from that time onwards experts, technicians, and employers' and workers' associations have been continuously contributing to advance this work of social improvement.

Moreover, the effect of occupational work on young persons, still in the period of physical development, is so marked, and is attended by consequences for the individual and the community which are so serious, that to-day no objection is raised to the principle of stricter intervention than has been hitherto adopted by certain countries.
Pende emphasises the existence of a sixth period of growth, which is of clinical import. Although very slow it is the last stage in increase of height of the body, a period extending from the twenty-fifth to twenty-eighth year to the thirty-fifth to fortieth year, the *constans aetas* of the ancients. This is the period of body maturity, both in shape and functions. Without entering upon the important question of the three fundamental laws of growth, it is enough to say that by their effects permanent characters either of the race or individual, just as if each function and each physiological reaction traced its individuality more or less deeply upon the skeleton (Testut).

Without going fully into details, it is enough to recall that the period of ossification is all important to the problem of growth. As early as 1909, Bosch, of Harvard University, in order to ascertain exactly the stage of development of children under fourteen years, had the idea of making radio-

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**Fig. 30.** — Increase as shown at corresponding points of the body during the period of growth in young boys of 13-17½ years of age (according to Gouin).

Normal changes in the intensity and rapidity of growth, as well as in its rhythm, may be interpreted either as a whole or in their elements. Deviations from this intensity, from this rapidity, or from this rhythm, when they exceed the limits of normal variations, appear as diseases of growth.

Progress in the formation of the bony skeleton determines the basis upon which the shape of the human body is formed; it reflects very clearly the grams of the bones of the wrist. According to this author, no other part of the body exhibits better and more easily than the wrist the changes, which occur during the period of childhood; hence the physical and physiological fitness of a candidate for definite work can be checked.

The fitness of children is decided in practice by facts relating to size, weight, chest measurement and by manifestations of puberty.
Still, age, race, sex, mode of life, personality, and even the methods of measurement adopted, as well as those for grouping and presenting the collected facts, are all possible causes of error, of which account must be taken. The formulae proposed for establishing the state of nutrition will be described later (under Hygiene).

In the rhythm of growth the periods of second childhood, from eight to fifteen years, and of adolescence are mainly of interest.

The following pages are confined to consideration of size, weight and puberty.

Height. — The body grows in males continuously up to twenty years and beyond, but the curve presents phases sometimes of increased, and sometimes of abated, activity. The intense development which occurs from birth to the sixth and seventh years is followed by a phase of relaxation till the eleventh and twelfth years. At this age, or later, increased activity in growth occurs which continues till about the sixteenth year, after which a fresh period of quite definite abatement in the progress of growth follows.

The height in females presents a similar curve, but the complete duration of each phase is slightly less, commencing and finishing two years before that for males and only rarely lasting beyond the twentieth year.

Weight. — From birth to the end of the third year weight increases following the same curve as height, and the annual amount of increment is almost constant till seven to eight years. Then follows a phase of annual increases, slow but regular, which lasts till the age of fourteen. Starting from the fifteenth year, the increase becomes more rapid and continuous till the seventeenth year; then follows a phase characterised by definite and progressive slowing down.

In the case of women, the period of the rapid annual increase commences as early as the eleventh year, but it ceases at the fifteenth year.

If these curves are compared they are found to be parallel for the two sexes up to the third year. Starting from that age up to adolescence the curves of growth move in opposite directions, but become parallel again after that. But at the period of rapid growth the curve of height for men precedes that of weight, whilst in women the curves are superimposed, the curve of height stopping a year before that of weight. During the period of one or two years preceding the period of rapid increases in weight no trifling increases occur.

Growth from second childhood to adolescence, as far as the height is concerned, is marked by a sharp rise, but in regard to weight it is marked by an accelerated and uniform rhythm.

It may then be said that the body first lengthens and subsequently gathers weight.

By his researches, Godin has been able to present a complete picture of
the adolescent type and to supply proof of the aphorism: “growth during puberty is chiefly muscular, and before puberty chiefly osseous”.

All experts agree on the point that important increases in weight, in chest measurement, and in the biacromial diameter are spread out over a greater period than that of height, and that they are still displaying continuous activity for some years after annual rates of increase in height have attained their maximum.

The period of puberty may be placed between the twelfth and eighteenth year. Height, according to most authors, reaches its maximum of increase some months before external signs of puberty; but other experts say that these two points in the physical evolution of adolescents coincide. Weight, on the other hand, displays its important increase at the time of puberty, an increase which lasts during its whole period.

Nevertheless, the age at which puberty appears varies according to race, environment, season, social class and the individual. It is besides necessary to take into account, when defining the time of its appearance, not so much the manifestations which accompany it, as the well known physical signs of puberty. This is all the more important on account of the fact that puberty — the manifestation of the development of the body — occurs by different phases in the course of different periods: amongst women, for example, the appearance of the signs of puberty are accompanied during all this period by a regression, one might even say by an arrest of the processes of organic oxidations.

Experts have emphasised the very close association which exists between the development of the figure and the first menstruation, as well as the very high rates of increase during the two years preceding the first menstruation.

The same phenomena may be stated to occur in men who, however, in temperate climates, show signs of puberty two years later than girls, that is between fifteen and sixteen years.

The fact must be emphasised that the appearance of these signs does not signify the completion of puberty, but only that it has reached its maximum.

Adolescence commences one and a half to two years before puberty and finishes one and a half to two years after. According to Godin, young persons of seventeen and a half to eighteen years are still adolescents.

According to this author, if the two sexes are compared, girls are found to come level with boys as regards weight at about the tenth year, and as regards height at the twelfth year. After this period girls pass the boys in both height and weight up to the fourteenth to fifteenth year; but thereafter it is the boys who lead, first in height and then in weight.

Choosing from among the numerous investigations made into the development of children reference is restricted to the following (see also later under Work and Growth and Pathology of Growth).

A comparative study by T. Yagi, of the Japanese Institute for the Study of Labour, directed by G. Teruoka, has emphasised that up to the age of twelve years the height and weight of girls employed in factories and of pupils in school are almost the same, but from that age the physical development is impeded in the case of the former, so that the difference between these two groups becomes greater each year.

In the same Institute, H. Kirihara has studied mental development in the young girl at school and at work. Starting from the twelfth year, he found that development was very good in both groups, but that it lastest in the case of the pupils till the sixteenth year, whilst in the case of the working girl development declined each year after the thirteenth year. Kirihara considers that girls enter factories at too young an age, and that monotonous work carried on under bad hygienic conditions further aggravates the position (see article “Women’s Work”).

In 1922, Tagliaferro, Clark, Sydentricker and Collins examined the height and weight of 14,335 white scholars, aged from six to sixteen years, in the States of Maryland, Virginia, and Carolina. Their investigations revealed the average heights of girls aged from eleven to fourteen years and of those aged from twelve to fourteen years as being higher than those of boys of the same age.

The index W/H, i.e. weight divided by height in inches, for the girls exceeds that for the boys, both at the age of twelve to fourteen years, and at the age of fifteen years, whilst at other ages it is higher for boys than for girls.

The annual increase of weight for girls from eight to thirteen years exceeds that of boys; for the other ages, it is greater for boys. However, if the annual increase in weight per inch of height is taken into consideration, one finds that, after the sixth year, it is at any age greater for girls
Principal Medical Officer of New South Wales gives the results of examining more than 200,000 children of school age. It supplies sufficient data either for determining standards of weight and height or for the more general study of growth.

Among problems which arise from the subject of growth, one of the most important and most delicate is that of poor nutrition, which is manifested in the

age. But, omitting the effect of variation in height, after the eighth year, girls vary in height more than boys of the same age.

In other words, girls after their eighth year vary more in weight than boys of the same age and of the same height.

A report for the year 1918-1919 by the most varied terms, and generally gets classed among constitutional types, rather than among diseases.

In this way, an index of nutrition has been established, based upon the relation between weight and height, and observed physical deficiency is expressed as a percentage and not in bald figures. The figures indicate a
superiority in the case of boys up to eleven and a half years, then in the
case of girls up to fifteen and a half years, followed again by a superiority
for boys. Whereas girls cease to grow towards their eighteenth year, boys con-
tinue to grow for some years later. This finding is, however, less useful than
that of growth calculated in percentage, that is to say, the relation that is
obtained by dividing the increase of growth for a definite period (twelve or
six months) by the height or the weight taken at the commencement of the
period under consideration.

The facts relating to children and adolescents at work will be dealt with
later on.

SOCIAL DATA

Advantage may be gained by mentioning here some facts relating to the
descendants of working-class families. Whilst taking into account the dif-
"iculties which occur in bringing together and comparing the facts in ques-
tion, as well as the lack of accuracy and errors which may weaken these
statistics, it is none the less true that they offer interesting results. By the
aid of data found in medical literature and of those collected by the consulta-
tion department of the Labour Clinic at Milan, Carozzi in 1913 published
statistics dealing with 16,918 working-class families:

<table>
<thead>
<tr>
<th>Industries</th>
<th>Number of families examined</th>
<th>Number of pregnancies</th>
<th>Per 100 pregnancies</th>
<th>Deaths per 100 viable births</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Living infants</td>
<td>Dead infants</td>
<td>Miscarriages</td>
</tr>
<tr>
<td>Chemical industry</td>
<td>357</td>
<td>1,166</td>
<td>46.4</td>
<td>43.1</td>
</tr>
<tr>
<td>Ore and metal industry</td>
<td>741</td>
<td>2,911</td>
<td>54.4</td>
<td>26.1</td>
</tr>
<tr>
<td>Pottery industry</td>
<td>136</td>
<td>632</td>
<td>45.0</td>
<td>28.4</td>
</tr>
<tr>
<td>Wood industry</td>
<td>35</td>
<td>91</td>
<td>29.5</td>
<td>8.7</td>
</tr>
<tr>
<td>Painting industry</td>
<td>1,506</td>
<td>3,144</td>
<td>50.6</td>
<td>20.4</td>
</tr>
<tr>
<td>Textile industry</td>
<td>3,043</td>
<td>8,686</td>
<td>46.2</td>
<td>46.3</td>
</tr>
<tr>
<td>Clothing industry</td>
<td>352</td>
<td>1,083</td>
<td>54.4</td>
<td>27.4</td>
</tr>
<tr>
<td>Animal and vegetable waste industry</td>
<td>198</td>
<td>611</td>
<td>53.0</td>
<td>36.6</td>
</tr>
<tr>
<td>Polygraphic industry</td>
<td>1,372</td>
<td>4,568</td>
<td>61.6</td>
<td>28.1</td>
</tr>
<tr>
<td>Lithographic industry</td>
<td>35</td>
<td>78</td>
<td>79.7</td>
<td>15.3</td>
</tr>
</tbody>
</table>
| Book-binding and cardboard manuf-
   acturing industry               | 50                           | 146                   | 47.9               | 35.7                       | 16.4                       | 42.6                     |
| Rubber industry                   | 35                           | 73                    | 61.7               | 20.5                       | 17.8                       | 25.0                     |
| Tobacco industry                  | 7,600                       | 29,680                | 58.2               | 33.8                       | 8.8                        | 36.8                     |
| Housewives                        | 1,926                       | 5,105                 | 59.1               | 29.9                       | 12.0                       | 32.7                     |
|                                   | 16,918                      | 57,304                | 55.9               | 30.4                       | 13.7                       | 34.9                     |

The high death-rate among the child-
ren of working-class families can be explained by several causes, among
which social conditions come first.

It is not possible to determine the part which is due to ancestral factors
and the part due to environmental factors. These latter react on the con-
stitution of the parents, and, during pregnancy, by the intermediary of the
mother, on the foetus; thus they are confused with pure by ancestral factors.

Studies in pre-natal infant welfare bear witness to the effects which the
social conditions of the pregnant women exert on the foetus.

Without going into fuller details regarding the effects of environment,
either natural or social, it is enough to note the importance of climate on the
viability of the newly-born, whether legitimate or not, and the age of the
child at which social factors act the most powerfully, i.e. during the first
months of life. The mortality of the newly-born of the working class is
highest in the first weeks, while in the leisureed class it is quite low. Weakly
children die when they pass from the intra-uterine temperature to the ex-
ternal temperature, according to Schloss-
smann and Zanchi. Funck, Eller and Zanchi have proved that this influence
also lasts throughout the first year, becoming much less in the following
years; but Bertillon, Verrijn and Stuart consider that this effect continues to be
felt during childhood and adolescence. It is well known that mortality from
infectious diseases, in particular from tuberculosis, is more frequent among
the children of the poor than among the children of the rich. If the social con-
dition of the parents is low, then the mortality of the infants is high. Illeg-
imate children, being the poorest among the poor, while the sufferings of the
mother during pregnancy and confinement also exert a detrimental
influence, naturally show the highest rates. After birth, these conditions continue to act. In addition, the following factors come into play: lactation, whether at the breast or artificial; early weaning; bad and wrong feeding, and housing. It is important here to refer to the enquiries of Villermé, Bertillon and Eichelberg, who found at Gladbach that the mortality among the nurslings of working class families varied according to whether the conditions of housing were up-to-date and hygienic, or old and insanitary, poorly lighted and badly ventilated. Similar results were collected by Villermé in 1839 for the town of Mulhouse. There must further be taken into account such factors as: hours of work; and wages, that is to say, economic conditions; the sanitary conditions of the town; the price of milk; the existence in the town of schemes for infant welfare. Obviously, the effects of all these conditions are ameliorated if the infant is fed at the breast instead of artificially.

Another feature of the problem which should be referred to is that of fertility. The fact is that lowest birth-rates are found in towns where malthusian practices are more generally adopted than in the country, and where marriages are less frequent, and, above all, do not take place so early. The frequency of marriages among working women was in Italy actually half that for the whole female population, and the frequency of confinements about a third. Jones, in Great Britain, years ago found that the average of births in seven towns, where there were hardly any women employed in factories, was 35.48 per 1,000, as against 28.15 in seven centres of the textile industry.

Moreover, the low birth-rate in industrial centres is generally accompanied by a high infant mortality; but this tendency, however, may be counteracted by the happy results of measures of assistance and propaganda for infant welfare adopted in the centres in question. In this way, in the Italian town of Sanpierdarena, with 65,000 inhabitants, child mortality up to twelve years of age has come down from 48 per cent. of the total death rate in 1901 to 22 per cent. in 1920, and for children below one year from 16.1 to 8.5 per cent. of births.

It is true that several enquiries, an English one of 1910 and an American one of 1922, raise some doubts as to, or even deny, the injurious effect of the industrial occupation of the mother on the children, and put in the first place the influence of other factors, such as the ignorance of mothers as regards infant feeding and deficiency in hygienic care. Robertson (1910) is of the opinion that the factor “social status”, i.e. the amount of poverty, is of more importance than the factor “work”. But the industrial working mother has recourse to paid wet nurses more often than the poor woman, and that is why the infantile mortality during the first year is considerably higher than that of infants of poor mothers (Finizio); the earnings of the industrial working woman are not generally sufficient to neutralise the harmful effects that arise from neglecting the welfare of infants — hence indeed, arises the importance of industrial crèches. Proof to the contrary is supplied by the infants of agricultural working women; they are breast fed and well cared for, and show much lower death rates.

**WORK AND GROWTH**

The normal progress of growth presents a true picture of the general state of the body. It is influenced by numerous factors: climate; season; mode of living; feeding; illnesses; sanitary conditions; work, either heavy or un healthy, or precocious, domestic or in the field; or economic conditions. It is merely intended to deal here with the factors, sanitary and economic conditions, and work.

The influence of hygienic and economic conditions on height and weight is proved by numerous researches, according to which the average height, and the weight of children of well-to-do parents at any given age are higher than those of poor children.

But, as regards height, the rhythm of growth is only influenced after the twelfth year, from which point the difference between the rich and the poor tends to increase.

The average weight of the children of the rich is always, at every age, greater than that of the children of the poor.

In conclusion, the poor grow more slowly and with more difficulty. Bad sanitation and low economic conditions place them definitely and permanently in an inferior position to that of the rich.

School medical officers are generally agreed that children from fourteen to fifteen years of age leave school for the factory too soon, and this is especially the case in industrial centres, where children are physically so below the average that they ought to attend for one or two years more before beginning any kind of work.
children and young persons

According to these experts only 42 per cent. of the schoolchildren examined in twenty German towns had a good physical constitution, 50 per cent. had an average constitution and 8 per cent. a bad one. Investigations made at Munich before the war showed that about half the schoolchildren had a good constitution.

Another enquiry, made at New York in 1924, dealing with 412 children, showed that: 18 had no physical defects; 99 had simple defects due to hygienic conditions; 179 had medium defects requiring slight medical attention and hygienic supervision; 93 showed serious defects causing a partial or temporary incapacity, capable of being overcome by adequate treatment; 16 showed bodily affections, or physical deformities which were capable of benefiting by treatment without medical supervision; 7 showed organic lesions requiring immediate medical intervention and probable cessation from work.

It is a common and just reproach that hygienic control of children and adolescents is not organised in every civilised country: far too much heavy work, for instance in ironworks, at transport, in the butchery trade, or at baking, is given to adolescents without their having been gradually accustomed to the work, and without their being placed under periodical medical supervision.

It is clear that puberty, which is a period of unstable and labile equilibrium in juvenile life, is affected by the harmful influence of any factor resulting from work: by sitting or standing; by close air or too much draught; by dust, steam, fatigue, strain, prolonged working hours, or night work. In such ways the body can at this time be shaped and moulded as wax by factors which act on it.

Several experts have studied the effect of physical work on growth and have compared the records obtained in the case of children at work with those obtained from children of the same age at school (Roberts, Cowel, Giordano, Bowditch, etc.).

The conclusion may be drawn that as regards height, weight, and chest measurement, increase of growth is less in girls in heavy work than in schoolchildren, and that, in consequence, the index obtained was an index of inferiority. The differences found between well-off and poor children, and between children at work and at school, are greater and more defined as the age rises and a period of adult life should characterise a race.

At the commencement of work, at twelve to thirteen years of age, height, according to Allaria, is said to be less for working girls than for young girls of rich parents; then it increases slowly, during puberty and stops much sooner than with the rich. The result is that in adult years the height of working women is less than the average height which under favourable conditions of life should characterise a race.

The weight of women workers is, at the beginning, lower than the average weight of rich young girls, and this constant difference is maintained subsequently. In working women the increase of weight during puberty is so retarded and difficult that the ultimate weight is very deficient compared with the requirements of ordinary physical development.

In the same way the average pulmonary capacity is always lower at the
same age in working women than in young girls of rich parents. At nineteen years the average value for the latter was 24 litres, for weavers it was 2 litre, and 1.6 litres for dressmakers in the case of whom occupational posture constitutes an obstacle to the normal development of the thorax.

At equal ages the muscular force of the working women was lower than that of girls in well-to-do families; in the case of the weavers it was deficient, even though they were of peasant origin, while the deficiency was greater in the case of the dressmakers. Premature and complete arrest in the growth of the body and in the development of the lung capacity has been found in working women at the age of seventeen years.

This deficient physique which is due to conditions before the young girls enter on factory life is aggravated during adolescence and during the working period, especially if they have a struggle to make a living.

The results of examinations made by English doctors of young persons of fourteen to sixteen years who applied for a certificate of fitness for work provide interesting points on the causes of final or conditional rejection. The number of young persons examined was 350,862 in 1923, 364,297 in 1924, 390,814 in 1923, and 267,964 in 1922. The percentage of young persons rejected for reasons of a medical kind (see below) was respectively 1.84, 1.78, 1.96, and 1.98. The percentage of rejections and of conditional certificates for the same reasons was 4.49, 4.14, 4.57, and 4.47.

The causes of rejection or for issuing conditional certificates for medical reasons may be classified as follows (the figures represent the total for the years 1922 to 1925 inclusive):

<table>
<thead>
<tr>
<th>Reasons</th>
<th>Total rejections</th>
<th>Definite rejections</th>
<th>Conditional rejections</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Absolute number</td>
<td>Per 100 reasons</td>
<td>Absolute number</td>
</tr>
<tr>
<td>Defective bodily development</td>
<td>708</td>
<td>2.93</td>
<td>1,981</td>
</tr>
<tr>
<td>Deformity (including old infantile paralysis)</td>
<td>177</td>
<td>0.73</td>
<td>710</td>
</tr>
<tr>
<td>Specific fevers</td>
<td>165</td>
<td>0.47</td>
<td>11</td>
</tr>
<tr>
<td>Pesticidus</td>
<td>16,33</td>
<td>55.50</td>
<td>6,339</td>
</tr>
<tr>
<td>Disease of skin</td>
<td>1,305</td>
<td>5.61</td>
<td>744</td>
</tr>
<tr>
<td>Disease of bones and joints</td>
<td>146</td>
<td>0.61</td>
<td>397</td>
</tr>
<tr>
<td>Disease of glands</td>
<td>448</td>
<td>1.85</td>
<td>994</td>
</tr>
<tr>
<td>Disease of lungs</td>
<td>634</td>
<td>2.62</td>
<td>598</td>
</tr>
<tr>
<td>Disease of circulatory system</td>
<td>1,335</td>
<td>5.61</td>
<td>2,367</td>
</tr>
<tr>
<td>Disease of nervous system</td>
<td>378</td>
<td>1.56</td>
<td>412</td>
</tr>
<tr>
<td>Disease of ear, nose or throat</td>
<td>1,822</td>
<td>7.51</td>
<td>4,202</td>
</tr>
<tr>
<td>Disease of eyes and eyelids</td>
<td>3,270</td>
<td>13.33</td>
<td>9,338</td>
</tr>
<tr>
<td>Other</td>
<td>256</td>
<td>1.03</td>
<td>4,062</td>
</tr>
<tr>
<td>Total medical reasons</td>
<td>24,155</td>
<td>100.00</td>
<td>32,795</td>
</tr>
</tbody>
</table>

An English enquiry dealing with differences in height and weight of workmen of rural or town origin gave the results shown in the table at the top of page 414.

In accordance with the Royal Belgian Decree of 1 June 1920, which instituted a hygienic survey of adolescents at work, doctors selected and paid by the employers as well as factory medical officers, have carried out the following number of examinations during the years 1924-1925:

The number of firms that organised health surveys was 1,960 in 1924 and 2,020 in 1925. The number who did not was 666 and 257.

The factory medical officers examined 14,040 adolescents in 1924, of whom 8,822 were men. The certifying surgeons examined respectively 37,967 adolescents in 1924, of whom 22,604 were men, and 48,045 in 1925, of whom 27,423 were men, and 48,045 in 1925, of whom 27,423 were men and 48,045 in 1925, or a total of 51,907 examinations in 1924 and of 63,420 in 1925.

An additional half-yearly examination was considered necessary for 4,680 persons in 1924, and for 5,027 in 1925; one every three months for 1,564 persons in 1924 and for 1,907 in 1925; and every month for 211 persons in 1924 and 287 in 1925.

The percentage of adolescents found in good health in 1924 was 93.69, compared with 98.61 in 1925; the percentage for men was 93.15 compared with 89.12 in 1925; and for young girls it was 94.36 compared with 87.93 in 1925.
DIFFERENCES IN THE HEIGHT AND WEIGHT OF WORKMEN OF RURAL AND TOWN ORIGIN

<table>
<thead>
<tr>
<th>Class</th>
<th>Number of men examined</th>
<th>Height in feet and inches</th>
<th>Weight in stones and pounds</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men brought up in the country</td>
<td>400</td>
<td>5:9</td>
<td>12:4</td>
<td>20-55</td>
</tr>
<tr>
<td>Men brought up in the public schools, cadets, etc.</td>
<td>a proportion of 1,000</td>
<td>5:9</td>
<td>11:1</td>
<td>90-99</td>
</tr>
<tr>
<td>Knife grinders, Sheffield</td>
<td>1,080</td>
<td>5:5</td>
<td>9:10</td>
<td>75-85</td>
</tr>
<tr>
<td>Copper workers, Birmingham</td>
<td>500</td>
<td>5:7</td>
<td>8:12</td>
<td>18-40</td>
</tr>
<tr>
<td>Engineers, Glasgow</td>
<td>298</td>
<td>5:2</td>
<td>8:5</td>
<td>20-30</td>
</tr>
<tr>
<td>Carpenters, Glasgow</td>
<td>980</td>
<td>5:5</td>
<td>9:1</td>
<td>18-40</td>
</tr>
<tr>
<td>Recruits, Manchester (Grade 1)</td>
<td>55</td>
<td>5:4</td>
<td>9:9</td>
<td>18-40</td>
</tr>
<tr>
<td>Ashton-under-Lyne (Grade 1)</td>
<td>37</td>
<td>5:2</td>
<td>9:3</td>
<td>18-40</td>
</tr>
<tr>
<td>Bolton (Grade 1)</td>
<td>3</td>
<td>5:5</td>
<td>5:4</td>
<td>20-30</td>
</tr>
<tr>
<td>Liverpool (Grade 1)</td>
<td>1,000</td>
<td>5:5</td>
<td>9:1</td>
<td>20-30</td>
</tr>
<tr>
<td>Preston (Grade 1)</td>
<td>3</td>
<td>5:5</td>
<td>5:4</td>
<td>20-30</td>
</tr>
<tr>
<td>Accrington (Grade 1)</td>
<td>1,792</td>
<td>5:5</td>
<td>9:0</td>
<td>20-30</td>
</tr>
<tr>
<td>Lancaster (Grade 1)</td>
<td>5:6</td>
<td>9:2</td>
<td>20-30</td>
<td></td>
</tr>
<tr>
<td>Warrington (Grade 1)</td>
<td>5:6</td>
<td>9:3</td>
<td>20-30</td>
<td></td>
</tr>
<tr>
<td>Chester (Grade 1)</td>
<td>5:6</td>
<td>9:4</td>
<td>20-30</td>
<td></td>
</tr>
</tbody>
</table>

1 Recruits for the Army: Report upon Physical Examination of Men of Military Age, published by the National Service Medical Boards (Cmd. 504).

Note the slight superiority of height of the recruits from Chester and Lancaster compared with those from the most important and most particularly industrial towns. The figures given above refer to men of the first grade; the statistics relating to 1,000 other men of the second grade show a much worse physical condition. (Journ. of med. Hyg., Jan. 1921, p. 326.)

The anomalies noticed by the factory medical officers during these examinations may be summarised as follows: vertebral column, 39 (37 in 1925); pelvis, 2 (2); limbs, labour; skin, scalp, 40 (20); heart and vessels, 26 (37); respiratory passages, 142 (145); of which, tuberculosis, 45 (171), and bronchitis, 10 (3); alimentary canal, 14 (30); mouth, 797 (976), of which, dental caries, 622 (737); enlarged glands, 175 (17); nose, 54 (24), of which adenoid vegetations, 41 (26); hernias and diseases of the sexual organs, 127 (143); nervous system, 6 (10); ear, 33 (118); eyes, 353 (478); various, 24 (15), 3 of which were lead poisoning.

In Sweden the Act of 1912 on the protection of labour requires an annual medical examination in which height and chest measurement are taken for every boy and girl admitted to work until the age of eighteen years. By making use of the particulars supplied by each person's docket, the statistical department of the Administration for labour and social supervision has studied the development of 35,445 boys and 8,436 girls (out of 65,000 docket) who, in each occupational category, had worked at least for three years in the occupation concerned without having passed into any other occupation and had three medical examinations.

These 43,881 young persons are classified by age thus:

<table>
<thead>
<tr>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 years</td>
<td>2,198</td>
</tr>
<tr>
<td>14 years</td>
<td>7,336 1,750</td>
</tr>
<tr>
<td>15 years</td>
<td>3,586 2,235</td>
</tr>
<tr>
<td>16 years</td>
<td>8,500 2,299</td>
</tr>
<tr>
<td>17 years</td>
<td>3,206 2,990</td>
</tr>
</tbody>
</table>

The boys were chiefly occupied in engineering works, saw mills, paper mills, textiles, boot factories and glassworks. The girls worked in the food industries, textiles, boot trade and lithographic printing.

The average weight, height and chest measurement are shown by age as follows:

**BOYS**

<table>
<thead>
<tr>
<th>Age</th>
<th>Weight (kg.)</th>
<th>Increase</th>
<th>Height (cm.)</th>
<th>Increase</th>
<th>Chest measurement (cm.)</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 years</td>
<td>39.2</td>
<td>—</td>
<td>147.2</td>
<td>—</td>
<td>69.4</td>
<td>—</td>
</tr>
<tr>
<td>14</td>
<td>40.1</td>
<td>3.9</td>
<td>152.1</td>
<td>4.9</td>
<td>71.9</td>
<td>2.5</td>
</tr>
<tr>
<td>15</td>
<td>45.1</td>
<td>5.0</td>
<td>157.8</td>
<td>5.7</td>
<td>75.2</td>
<td>3.3</td>
</tr>
<tr>
<td>16</td>
<td>50.3</td>
<td>5.2</td>
<td>163.3</td>
<td>5.5</td>
<td>78.8</td>
<td>3.6</td>
</tr>
<tr>
<td>17</td>
<td>54.7</td>
<td>4.4</td>
<td>167.3</td>
<td>4.0</td>
<td>81.8</td>
<td>3.0</td>
</tr>
</tbody>
</table>
It is easy to notice here also that increase in height precedes increase in weight and in chest measurement. The same facts are given for girls as follows:

<table>
<thead>
<tr>
<th>GIRLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
</tr>
<tr>
<td>14 years</td>
</tr>
<tr>
<td>15 ..</td>
</tr>
<tr>
<td>16 ..</td>
</tr>
<tr>
<td>17 ..</td>
</tr>
</tbody>
</table>

These results lead to the same conclusions as for the boys. It is again found that for girls the period of active growth, properly so called, as well as the maximum increase in weight and in chest measurement, generally takes place at an earlier period than for boys. This peculiarity is due to the fact that the period of puberty, as we have seen, terminates generally in girls between the fourteenth and fifteenth year, from which results that, by maturing thus early, girls of fourteen are more developed, from the triple viewpoint of weight, height and chest measurement, than are boys of the same age. But during further development boys exceed girls first in height and, later, in chest measurement and weight.

The Swedish investigation has shown that children of less than thirteen years, as regards height, weight and chest measurement, form a group the data for which are somewhat asymmetrical, in the sense that individuals whose height is less than that of the normal type are relatively less well represented than individuals who are taller. Close analysis of the statistics leads to the conclusion that selection of individuals of less vigorous physique has attached to the figures for weight a greater importance than to those for height or chest measurement.

In addition the enquiry has confirmed that differences in physical development between thirteen and seventeen years correspond in a certain degree to initial differences of development existing at the age of thirteen years. According to a table based upon data derived from the special examination carried out, with a view to selecting individuals who have been under continuous observation between the thirteenth and seventeenth year, increases of weight and height among children belonging to the extreme categories when under thirteen years, develop less during the period in question than in individuals who had belonged to the middle category. This difference is less accentuated as regards the chest measurement.

A similar investigation carried out in the case of girls proved that development in weight, height and chest measurement, between ages fourteen and seventeen, is on the average more pronounced for the smallest of the girls at age fourteen than for those who were more advanced at the start. This slowing down of growth does not seem to have an equivalent in the case of boys, who are less developed at the start. This fact would seem to prove that the period under discussion is for girls less critical than for boys, for whom it coincides with puberty.

Several enquiries deal with children employed in the most varied occupations, which, it must be confessed, do not show the same standards of hygiene and healthiness. Reference may be made to the enquiries of Dementiev made in the Russian textile industry; of Erisman, also from Russia; of Frongia, in the Sardinian mines; of Allaria, made among spinners and dressmakers in Turin; of Giordano, among miners of Sicily; and of Roberts, of Great Britain, who has emphasised the beneficial effect of legal protection on the growth of English children. As a matter of fact, children who in 1833 from the age of eleven years passed half the day at school and the other half at the factory showed an average height of 136.4 cm. In 1900 the half-time system was prohibited for those younger than twelve years; and seven years later the average height of children of this age was 139 cm. The average weight also rose from 31.4 kg. to 34 kg.

The facts collected in 1926 by Kose and Itani on 1,683 children of Nagoya, Japan, employed on half-time in the textile or pottery industries, or on toys or machinery, have established that the age of admission to work has been for some seven years; for others, from eight to nine years; and for most ten
years. Admission to work at too early an age is found most often in the case of girls. The figures for height, weight, and chest measurement, compared with those for 45,000 scholars, show that, with the exception of children aged seven years, they are always lower for children employed on work.

Reference should be made to the article "Women's Work" for the effect of work on the pregnant woman, on the foetus and on the mother. It need only be remarked here that children born of tired women are particularly liable to be seriously affected as regards their development and their viability — a condition especially pronounced in the case of children of women employed on heavy or unhealthy work, or where poisons are handled which act on the sexual and maternal function.

There follows here a somewhat rapid sketch of examinations made of children and adolescents employed in industry. It completes what has been said above and helps to emphasise the injurious influence exerted on the normal progress of puberty or the aggravating influence exerted on pre-existing physical weaknesses.

Erisman found in some occupations that the development of chest expansion and weight is retarded, although height increases at its normal rate.

Hahn has found that, in the case of bakers' and gardeners' apprentices of Munich, the average values for height and weight, as well as the ratio H/W, are lower than in the case of students.

The bakers' apprentices showed defects of the skeleton, with pulmonary and cardiac lesions of a more serious degree than did the gardeners' apprentices.

Schlesinger has also pointed out decided differences between anthropometric data for boys at work and boys at school of the same age in Strasburg.

As a result of an enquiry made among apprentices at Munich, Kaup found among blacksmiths, butchers, locksmiths, tailors and bakers a large number of diseases and constitutional anomalies attributable to work. Kaup classifies the adolescents examined into three groups.

First, persons with deficient physical development and deficient chest measurement as the result of unfavourable external conditions. This poor nutrition is a cause of inferiority, which extends throughout the period of occupational work; it is due to work under unfavourable conditions, and to lack of functional stimulation. Type: tailors, clerks and shop assistants.

Second, persons with physical development above the average, but of less breadth, for lack of sufficient stimulus to development of breadth and of adequate nutrition. Type: clerks and students.

Third, persons with almost normal development, with development in correspondence, as regards height and chest expansion, as a result of normal conditions of nutrition and activity at the student period and of sufficient stimulus for the development of height and chest expansion in the occupational period, during puberty. Type: blacksmiths and butchers.

Height and chest measurement are in close relation to the development of other systems and organs. The curves of development for the heart and for weight are parallel. The expansion of the thorax influences to a certain extent the position of the abdominal organs. It is also considered that bad conditions of nutrition and various influences due to work (toxic substances in particular) may intervene, setting up reactions which interfere with various hormones.

In 1909-1910 Winter, on examining 3,436 apprentices of Vienna, found that 10 per cent. required medical supervision and that in 40 per cent. the general state of health was mediocre or bad. Among other things, he found in 20 per cent. anaemia, in 20 per cent. defects of sight, in 2.5 per cent. deafness, and in 20 per cent. dental trouble; 605 apprentices suffered from impairment, that was either congenital or acquired, of the various organs.

Berger found constitutional defects in a seventh of the students at training schools at Crefeld. Kaup found that of the apprentices of Munich, on an average 11.6 per cent. had infiltration at the apex of the lungs; 8.6 had cardiac defects; 36.48 had struma; 13.7, nervous disorders; 31.5, defects of vision; 21.4, rickets; 12.3, scoliosis; and 26.75, flat feet.

In Sweden, the medical examination of 45,000 adolescents, of whom 12,000 were girls of from thirteen to seventeen years of age, has established the facts that, in 1920, 15 per cent. had organic defects, of which 2.4 were of the skeleton, 1.6 of the heart, 0.4 had tuberculosis, and in 1.2 the lymphatic system was affected. Of these adolescents, 1.5 per cent. had been discharged from work and 23.6 had been admitted conditionally or had been employed in other occupations.

An Austrian enquiry in 1910 showed that, in the case of 22.6 per cent. of the schoolchildren examined, the state of health was not good, and that, whilst this state was found in only 17.3 per
Among these latter, the state of health was not good in the case of 50 per cent. of glassmakers; in 46.5 per cent. of boys employed in the manufacture of metal capsules; in 33.7 per cent. of textile operatives; in 45.8 per cent. of fringe makers; in 42.7 per cent. of makers of hair nets; in 38 per cent. of dressmakers; and in 57 per cent. of workers in glass beads.

Apprentices to the metal industry were examined by Epstein, who has placed on record the obstacles put by work in the way of normal development, especially as regards the chest and lungs.

Heart disease, which at Munich affected an average 8.6 per cent., was found to affect 11.3 of clerks, 11.6 of tailors and 15.1 of bakers. The degree of anaemia among young persons in the two last of these categories was in direct proportion to the duration of the period of work. As a matter of fact, Epstein found that the incidence rate was 1.6 per cent. for bakers and 8 per cent. for tailors on beginning work; but it reached 13.6 and 9 per cent. at the end of the first year, and 23 and 16 per cent. at the end of the second.

While scoliosis shows an incidence of 11.6 per cent. as an average for all occupations and only 6 per cent. for blacksmiths, it reaches 17.22 per cent. for tailors, varying from 10 per cent. in the first year to 20 per cent. in the third. Flat foot was found in that adolescents do not as a rule enter this occupation till sixteen years of age.

Mention may be made of deformities of the fingers as the result of accidents, of hernias and varicose veins. As regards hernias, Opitz noticed in apprentices an incidence of 5.8 per cent. against a general average of 1.4 per cent.; 15.5 per cent. among metal workers; 10.5 among wheelwrights; 8 to 10 per cent. among foundrymen, boilermakers and bakers; 0.8 to 2.2 per cent. among students, clerks, hairdressers and shoemakers.

Deformities of the skeleton show a rate of 22 per cent. for turners, mechanics, opticians, watch-makers and shoemakers. *Genu valgum* or *genu varum* has been found on an average in 7 per cent.; but it varies from 14.1 in bakers and 12 per cent. in turners, wheelwrights, blacksmiths, to only 4 per cent. among students and clerks.

It is the same in the case of dental lesions, due to sugar and flour. Whereas a bad set of teeth is generally found in 21 per cent. of persons examined, among pastrycooks the percentage is 51 per cent. (Rose).

Attention must be drawn to the fact that work exercises its injurious influence on the body of adolescents in a comparatively short space of time.

This fact has been proved by the investigation of Zinsli, carried out on the textile workers of Appenzell. Menishausen, on behalf of the State of Baden, and Winter, on behalf of Austria, have found that the height of men increases with the importance of their native village. Tallness may be accompanied by a degree of weakness which is due to the fact that most of these persons work in the sitting position in confined places and in a wrong posture. This condition is not reported from rural districts. During periodical medical examinations, it is certainly difficult to separate the influence of the factor "work" from that of other factors, such as family or social environment. However, an enquiry in 1921 by Mitchell, of Newark, dealing with 1,200 students at secondary schools for apprentices, showed that 6.5 per cent. of boys and 9.2 per cent. of young girls had received medical attention on account of poor nutrition. As regards weight, 22 per cent. of the young girls were considerably under weight from that cause.

Out of those classified as suffering from deficient nutrition 35 per cent. had orthopaedic defects as well, which were found in only 17 per cent. of well-nourished young girls. According to this author, these defects were due to work
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carried on in a wrong attitude, predisposing to tuberculosis. This expert has no doubt of the existence of a connection between the industrial work of adolescents and tuberculosis. As a matter of fact, 12.5 per cent. of the boys had early forms of tuberculosis of the lungs, and 13.5 per cent. were under suspicion; 16 per cent. of the young girls had early pulmonary signs, and 16 per cent. of the young girls had early forms of tuberculosis of the lungs. Of the young girls, 12.8 per cent. of the boys had lesions and 13.5 per cent. were under suspicion; 16 per cent. of the young girls had early forms of tuberculosis of the lungs. The expert found these defects grew worse under the influence of work in 68.6 per cent. of the boys and 57 per cent. of the young girls. In the same way as regards teeth, which were examined six months after commencing work, the condition was bad in 58.9 per cent. of boys and 57.5 per cent. of young girls.

Another interesting enquiry into the health of 2,076 children at work is that made by Jago Galdston in 1925 at New York. These children were aged from fourteen to seventeen years and able to attend a secondary school on one morning or one afternoon each week. The statistics deal with 2,000 children, of whom 433 had been subjected to a second examination. Of these 2,000 children, 264 were aged fifteen years. 978 were sixteen years, and 758 were seventeen years. According to weight, height, appearance of the mucous membranes and the muscular tone, more than a third were regarded as being in a state of under-nutrition; 6 to 18 per cent. and even more, of the children showed a weight lower than the average; only 54 per cent. showed a weight above it. Defects of sight were present in 540 children; 60 had other eye diseases; 87 had diseases of the ear, including 4 cases of diminished hearing; about one-half, some 45 per cent., were affected with dental caries; 154 had cardiac lesions; more than half had large tonsils which required surgical treatment; 187 had polypi of the nose, or upper respiratory passages; numerous cases of dermatitis and of orthopaedic defects, were noticed. The examination of the respiratory apparatus showed 6 cases of active tuberculosis, 31 of suspected tuberculosis, and 10 of the chronic kind.

Of these 2,000 children, only 225 could be considered as in a good state of health; 620 had at least one defect; 645 had two; 374 three; 135 from four to six; one child showed ten.

Galdston concludes that in present-day conditions of work few children escape tuberculosis infection and that the number of children over fourteen years who are not infected is very small. It must, however, be borne in mind the natural powers of resistance and immunity which develops in persons exposed to the danger.

PATHOLOGY OF GROWTH

A number of facts show the unfavourable action of occupational work on the development of puberty. Of the morbid conditions are even known under the name of "diseases of adolescents".

Among diseases of growth — dysgenesis — the best known to-day are the following: heart disease of the young or "juvenile heart", which might also be called "irritable heart of adolescents"; syndromes of growth of the locomotor apparatus — the fibro-, osteo-, and chondropathies of growth — which include the important adolescent curvatures of the spine, and the algias — tarsalgia and metatarsalgia; and the deformity of Madelung; the functional albuminuria which occurs at puberty or in the condition of lordosis (ren juvenum); the neuropathies and psychopathies of growth, which are syndromes of disturbed equilibrium of the sympathetic nervous system; pathological conditions of the skeletal apparatus — such as chlorosis and chloro-anaemia; infantilism and bodily and sexual wrong developments; and pathological precocities. (For fuller details see the report of Pende.)

These conditions will now be reviewed in brief.

The skeleton. — Curvatures of the vertebral column, such as scoliosis and kyphosis, the foundations of which may have been laid in school days, are certainly aggravated by conditions of work. Schlesinger has reported them in 12 to 17 per cent. of adolescents aged fourteen years and in 14 to 24 per cent. between ages seventeen and twenty-four. According to Scheuermann, these curvatures are found among workers employed in heavy and agricultural work. Blanchard claims to have found rates as high as 66 per cent. among young persons working at home in the American clothing industry.

In the spring of 1925, Jankowsky and Wigilew examined 779 adolescents in the Podolsk district: 483 from the engineering industry (383 young men and 100 girls) and 274 textile workers (139 men and 135 women).

The proportion of anaemia, 18 per cent., and of tuberculosis, 27.5 per cent., was fairly high. Workers in the engineering industry showed higher
rates compared with the textile workers on account of heart affections, diseases of the ears, nose and throat, digestive disorders, and eye diseases with 8.6 per cent. against 2.5 for textile workers. The general state of health was poor and the development irregular (6.4 per cent. against 2.5 for textile workers). A little more than a third of all workers examined were in good health.

Medical examination of a group of 412 Russian children showed that 28 per cent. of the defects found had been aggravated by work and that this aggravation affected 40 per cent. of the children observed. The defects found were classified as follows:

<table>
<thead>
<tr>
<th>Defects</th>
<th>Cases observed</th>
<th>Number of aggravated cases</th>
<th>Number of cases not affected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>Per cent.</td>
</tr>
<tr>
<td>Faulty department</td>
<td>169</td>
<td>143</td>
<td>84.6</td>
</tr>
<tr>
<td>Hernial, varicocele</td>
<td>7</td>
<td>6</td>
<td>85.7</td>
</tr>
<tr>
<td>Defects of vision</td>
<td>73</td>
<td>17</td>
<td>23.2</td>
</tr>
<tr>
<td>Cardiac lesions</td>
<td>17</td>
<td>10</td>
<td>58.8</td>
</tr>
<tr>
<td>Pulmonary lesions</td>
<td>11</td>
<td>3</td>
<td>27.3</td>
</tr>
<tr>
<td>Nervous exhaustion</td>
<td>28</td>
<td>8</td>
<td>28.6</td>
</tr>
<tr>
<td>Other defects</td>
<td>477</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Unsuitable conditions of work, recognised in 244 cases to have aggravated the pre-existing organic faults, were as follows:

<table>
<thead>
<tr>
<th>Conditions of work</th>
<th>Boys</th>
<th>Girls</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggravated cases</td>
<td>Per cent.</td>
<td>Aggravated cases</td>
<td>Per cent.</td>
</tr>
<tr>
<td>Position of prolonged standing</td>
<td>85</td>
<td>76.6</td>
<td>47</td>
</tr>
<tr>
<td>Position of prolonged sitting</td>
<td>1</td>
<td>0.9</td>
<td>35</td>
</tr>
<tr>
<td>Handling of heavy weights</td>
<td>5</td>
<td>4.3</td>
<td>—</td>
</tr>
<tr>
<td>Defective seat</td>
<td>12</td>
<td>10.8</td>
<td>28</td>
</tr>
<tr>
<td>Eyestrain</td>
<td>3</td>
<td>2.7</td>
<td>10</td>
</tr>
<tr>
<td>Bad lighting</td>
<td>3</td>
<td>3.6</td>
<td>15</td>
</tr>
<tr>
<td>Nervous exhaustion</td>
<td>1</td>
<td>0.9</td>
<td>7</td>
</tr>
<tr>
<td>Defective ventilation</td>
<td>—</td>
<td>—</td>
<td>4</td>
</tr>
</tbody>
</table>

It may be noticed that boys are more affected by prolonged standing than girls; but that the latter are more affected by prolonged sitting and by wrongly constructed seats.

Some illustrations of normal posture and of wrong postures, exaggerated by occupational work, will explain better than a long description the problem under consideration.

Among the deformities of the skeleton should be mentioned chiefly genu valgum, characterised by deviation of the legs outwards with projection of the knees inwards. It commences between thirteen and eighteen years of age and occurs chiefly in predisposed persons employed in occupations requiring prolonged standing. Genu varum is characterised by deviation of the limbs inwards with projection of the knees outwards; it is much rarer than the preceding and may be due to the same causes.

Tarsalgia, or painful flat feet, occur frequently in young persons and readily affect young persons of thirteen to eighteen years who are growing rapidly and are employed too early on an occupation requiring prolonged standing.

Carrying heavy loads undoubtedly tends to develop this lesion. It is characterised by weakening of the plantar arch, by turning outward of the sole of the foot, and by pain which precedes or accompanies the deformity.

An enquiry made in New York relative to 412 children (206 girls and 206 boys) under sixteen years of age and employed in any occupation for not less than six months has shown distinctly that a quarter of the children were only provided with seats which compelled them to assume such defective postures as would certainly result in deviations of the vertebral column.
GOOD ATTITUDE (A, B) AND BENT ATTITUDE (C, D)

Note in A and B the correct line of the back and the abdomen, and the position of the shoulders. A line drawn vertically passing by the ears falls towards the middle of the foot.

Note in C the pronounced kyphotic curve and the centre of gravity falling on the heels.

Note in D the pronounced kyphotic curve, the abdominal relaxation and the bent position of the head.

DEFECTIVE POSITION ACCENTUATED BY A STANDING POSITION OR EXCESSIVE WALKING

Relaxed abdomen and kyphosis. Office boy aged fifteen years ten months. Worked for four and a half months; 60 per cent. of day standing; and 40 per cent. walking.

Bent attitude; relaxed abdomen. Errand boy aged fifteen years nine months. Worked for six and a half months. Often carries heavy weights. 30 per cent. of day standing and 70 per cent. walking.

Kyphosis and relaxed abdomen. Saleswoman aged fifteen years nine months. Worked for six and a half months. Standing or walking 90 per cent. of the day.

Bad attitude generally. Thin girl and too tall aged fourteen years ten months. Worked six and three-quarter months. Messenger; walks 90 per cent. of the day.
The girls were more seriously affected by this defect than the boys.

Another enquiry carried out among 100 adolescent Russian dressmakers’ apprentices, aged from fifteen to eighteen years, led to Kaznelson finding deformities of the skeleton in 91 adolescents. Deformities of the thorax were present in 23 per cent., 34 per cent. of 54 per cent. who had deformities of the vertebral column were affected with scoliosis (32 per cent. to the left and 2 per cent. to the right); 12 per cent. with kypho-scoliosis; 7 per cent. with kyphosis, and 1 per cent. with lordosis.

When these results were compared with those of 9,000 schoolchildren examined by the surgical staff of the same clinic, it was found that the school-children were affected with scoliosis in a proportion of 19 per cent. and of deformities of the thorax in a proportion of 14 per cent. While in apprentices dressmakers the scoliosis is mostly with convexity to the left, in school children it is generally to the right, which is explained by the position of the body in dressmaking and at school.

If the time spent at work be taken into consideration, it will be found that scoliosis affects 28 per cent. of dressmakers who have worked two years, 40 per cent. of those who have worked two to three years, and 73 per cent. of those employed more than three years.

Variations in the shape of the thorax, difficult or stunted development, affectations which arise from these in the aeration of the lungs, and bad air in workplaces, all are factors which combined with external factors, favour the development of tuberculosis in these youthful bodies.

The muscular system does not escape the injurious action of the factors just mentioned. Work requiring excessive muscular force, or the use of certain groups of muscles or of certain muscles, whilst others remain inactive, may, in the long run, cause a great many disorders of nutrition in the muscular tissue, and more or less serious lesions in development, such as atrophy, hypertrophy and hernias of muscles, which are dealt with in the article “Occupational Diseases: Locomotor System.”

The whole circulatory system is also liable to be affected by the factors enumerated, which favour disturbance in the balance of the nervous system of young neuropathic workers. Such young persons suffer from general weakness from enlargement of the cardiac area, and from disorders which are associated with disorders of the circulation. An observer may notice the facial pallor of these youths; it is due to constitutional weakness of the circulation, described by Benjamin. In some cases at least an early arteriosclerosis either general or localised to the upper limbs is present due to heavy work, to strain and to poisons, whether occupational or not, such as lead, nicotine and alcohol.

Dealing with the senses, sight is certainly the one that is most affected. Work of all kinds which by its preciseness or the small size of the object handled necessitates visual effort, and also bad or insufficient lighting, provoke in children not only disorders of vision or aggravate a pre-existing myopia, but, in addition, give rise to general disorders, such as headaches and neuroses.

All the conditions which have just been dealt with cause serious injury to the physical constitution of the child, to his character, as well as to the normal development of his intelligence.

Adolescents who after a period of occupational work return to school are generally much less quick to learn than those who have not left their studies — those whose intellectual development has not been interrupted by too early employment.

An American enquiry carried out among children employed in growing sugar beet in Michigan and Colorado showed that 20 to 30 per cent. of them were backward at school, compared with those who did no work.

Another enquiry made in three States of U. S. A. showed that about 71 per cent. of children from eight to sixteen years of age working on farms were a year behind at school. A third enquiry made in rural districts on 11,000 children proved that 38 to 69 per cent. of white children and 71 to 89 per cent. of negro children working from one to six years behind at school.

From the moral point of view, observations made in seven large American towns on 9,278 delinquent boys showed that 56.5 per cent. were out at work. Out of 561 delinquent girls, 62.2 per cent. were also at work. These percentages, compared with those of children of the general population, tend to show that offences are more numerous among children put to work too young than among others.

The proportion of delinquents was especially marked among little newspaper boys, also among errand boys, and, as regards girls, among domestic servants.

Among young girls occupational work causes well-known disorders: pallor, anaemia, chlorosis, constipation, and, especially, disorders of sexual development, such as dysmenorrhea, meno-
and metro-rrhagia, abdominal pains, and hysterical nervous disorders.

The statistics of the Sickness Insurance Offices show the incidence of sickness among young persons. This incidence is fairly high; it does not appear immediately on the adolescent commencing work, but some years later, when the injurious causes have had time to act. This condition is seen for instance among tailors, shoemakers, boiler-makers, blacksmiths, printers, bakers, and painters. A fact admitted by most experts must not be forgotten, namely, that children and adolescents of feeble constitution enter by choice certain kinds of occupation, where they are more liable to become the victims of diseases, especially of tuberculosis, and to have their condition aggravated by such accompanying social factors as bad housing and insufficient nourishment, leading up to muscular weakness, and to have their condition aggravated by such accompanying social factors as bad housing and insufficient nourishment, leading up to muscular weakness, anaemia, and lowered resistance to infectious diseases.

The Sickness Insurance Office of Leipzig gives as the incidence of sickness, including accidents, for insured persons of fifteen to nineteen years of age, a rate of 37.3 for boys. The following age group, that is from fifteen to twenty years, but only 53.7 and 51.7 for the two following groups. This incidence of sickness is greater among young girls. As a matter of fact the Leipzig statistics give rates of 32.3 (without including accidents) for the age group fifteen to nineteen years against one of 25.7 for boys and a duration for each case of sickness of 21.7 days, against 17 for men.

In the industries which require a similar amount of exertion, when they are taken into account, it will be found that the sickness rate is almost always more unfavourable for young girls than for boys (Koelsch). In munition works young girls of sixteen to twenty years showed a sickness rate 30 to 40 per cent, higher than youths of the same age. Girls under nineteen years of age were affected with malaise, fatigue and weakness, two and a half times more frequently than men. Thus, for example, per 100 members of the Sickness Insurance Office aged from fifteen to nineteen, anaemia figured in the case of men with a percentage of 0.6 and in the case of women with a percentage of 7.9, or fifteen times more.

**Hygiene**

Physiology, on the one hand, and pathology connected with work, on the other, prove to us that children must not be admitted to work too young. At the age of twelve for example, nor at ages thirteen to fourteen, years be employed on heavy work at engineering or mining, if maturity is to be attained with good health and a vigorous body.

The protection of the child and adolescent is concerned with a number of questions of the first magnitude: a minimum age for employment; medical examination of physical fitness for employment; periodical examinations; hours of work; rest intervals; weekly rest; night work; and feeding.

For some years past there has been a definite tendency, especially in some countries, e.g. the United States, to raise the age of admission to work and to fix it at sixteen years. But having found that even at this age quite a large number of young persons entered the factories without having reached their full development, several American States have laid down laws for the protection of childhood which may usefully be mentioned.

Some States give to controllers or an inspector the power of subjecting boys to a medical examination when they find that these youths are not physically fit for the work on which they are occupied; others confer on the officer appointed to issue the certificate for work the right to examine any youngster that does not appear to be in good physical condition. Other States have laid down regulations for a compulsory medical examination for any youth who applies for a certificate to work. This examination must take into account the work which the youth wishes to take up and should be repeated each time that the occupation is changed.

Up till 1921 no American State provided for a periodical medical examination of adolescents, but since then twenty-two States have raised the school age and have organised a medical supervision of schoolchildren, thus making the work of the certifying doctor easier.

The reader may be referred to the resolution passed by the Special Commission for Child Labour at the meeting of the International Association for Labour Legislation, held at Basle in 1913. Here it suffices to repeat the standard proposed by the Children's Bureau of the Labour Department of the United States and by the Conferences on Standards of Child Welfare (1919-1923), which includes, on the one hand, medical examination by an official (a school medical officer or a
medical officer of the public health department) and, on the other hand, an examination for admission to work for children and adolescents up to eighteen years of age.

Among the general recommendations we find that the minimum age of admission is fixed at sixteen years. The Commission recognises that puberty may appear at an earlier or later age, and that, in the latter case, the youth should — the Commission is emphatic on the point — undergo a period of apprenticeship, during which the lad should not be employed on hard work.

No youth of from sixteen to eighteen years should be admitted to an occupation unless he shows a normal development for his age, good health and the fitness required for the work he has chosen. The medical examination should be made with the child stripped, should be repeated periodically up to the age of eighteen years, and every time the occupation is changed.

It is the duty of the local authorities to investigate the conditions of industry and occupation in their district, so that they can judge of the fitness of candidates, and the effects that conditions of work exert on the health and development of young persons.

As a minimum standard of physical fitness the average rates of normal development given below are adhered to, and any child who has not this minimum of weight and height is excluded:

<table>
<thead>
<tr>
<th>Age (in years)</th>
<th>Height (in cm)</th>
<th>Weight (in kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>153</td>
<td>36.287</td>
</tr>
<tr>
<td>15</td>
<td>158</td>
<td>38.555</td>
</tr>
<tr>
<td>16</td>
<td>163</td>
<td>40.823</td>
</tr>
</tbody>
</table>

1 If not clothed, not more than 2.2 kg. should be allowed for the clothes.

If a child has not this minimum he should only be admitted to work when two doctors certify him as fit. But exclusion should be absolute for any child that does not show external signs of puberty.

A certificate of fitness should be refused to any child affected with non-compensated disease of the heart; with tuberculosis or other serious disease of the respiratory organs; with active tuberculous glands; with active tuberculosis or syphilis of the bones or joints; with total blindness; with complete deafness, but admitting conditionally those who can be re-educated; with trachoma, chorea, syphilis, hyperthyroidism, acute or subacute nephritis, or ankylostomiasis. These children should be sent to institutions or to associations and polyclinics, which provide the assistance necessary for each being expressed in centimetres, the subject being seated.

For nurslings developing normally and normal adults the quotient $H$ expressed in centimetres will be approximately 100. For children in the growing state it is about 94.5. The extreme variations are from 89 to 109. A rate above 100 indicates hypernutrition, and one below 94.5 undernutrition.

A Swedish enquiry has also studied the question of a vital index showing the progress whether more or less satisfactory, of physical development, independent of the absolute rates of these measurements. It recalls the formula

$$T = \frac{100P}{H}$$

where $P$ represents the weight in grammes and $T$ the height in centimetres.

But this formula, proposed by Rohrer, has now only historical interest and is liable to numerous inaccuracies. Investigators are considering whether in the case where not only data for height and weight are dealt with, but for chest measurement as well, it would not be better to replace the formula of Rohrer by the following:

$$T=\frac{100p}{H}$$

where $pt$ represents the chest measurement. By the help of this formula, starting from the average data collected during an enquiry on juvenile workers of both sexes, the investigators obtained the following results:

<table>
<thead>
<tr>
<th>Boys...</th>
<th>5.11</th>
<th>5.10</th>
<th>5.05</th>
<th>5.06</th>
<th>4.96</th>
<th>4.88</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girls...</td>
<td>5.29</td>
<td>5.25</td>
<td>5.21</td>
<td>5.21</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In Switzerland the physical fitness of recruits is determined by means of the formula $F = H - (C + P)$ where $H$ is the height in centimetres, $C$ the circumference of the chest, and $P$ the
particular case. A certificate of admission should be refused unless the defects found are treated in a suitable manner. Thus visual defects require glasses; contagious diseases of the skin and teeth, appropriate treatment; dental defects call for dentistry and extractions; poor nutrition demands nourishment; while surgical attention is required for hernia, interference with nasal breathing, running from the ears, and orthopaedic defects; and suitable medication for intestinal parasites.

A provisional certificate, for a period of three months, may be issued if the treatment commenced is not yet complete, in the case of: poor nutrition, orthopaedic defects, diseases of the teeth, nose, ears, intestinal parasites, partial blindness or deafness.

Another interesting example is that of examinations arranged in Great Britain for young persons of from fourteen to sixteen years, which provides for a half-yearly examination for young persons of sixteen to eighteen years employed in certain industries. The results of these medical examinations have already been given above.

The essential object of this legislation is choice of work suited to the physical fitness of the candidate so that he has an average chance of continuing his occupation in years to come without exposing himself to risk of injuries affecting his normal development and his state of health. The certifying surgeon should always have in mind the aphorism that the child of to-day is the father and man of to-morrow. The certifying surgeon has a great responsibility towards workers, for he must avoid admitting as their fellow-workman anyone affected with contagious diseases, or with any kind of affection liable to cause any kind of harm to others.

In the case of the English factory surgeon, the object of the certificate of fitness is to declare that no physical disease and no kind of infirmity renders the candidate unfit for the employment in question and for the period of work laid down by law.

In the same way as the American legislation, British law provides for absolute or conditional rejection, admission or exclusion from certain work or certain operations; it requires that account be taken of the home surroundings of the candidate, of the general condition of hygiene in the factory where the candidate wishes to enter, of special conditions in certain operations which he will have to perform, and of the risk of accidents.

The certifying surgeons study the hygienic and sanitary conditions of the industries in their districts, so as to be always in a position to advise young candidates well.

Without entering into details which would lead too far, it will suffice to say that the definite opinion given by the surgeon, based on physical and psychic examinations, should also take into account the characteristics and the requirements of each occupation, the direct and indirect causes of injuries or dangers, as well as the influence which each occupation may exercise on the constitution and the personality of candidates.

Control of the employment of children working at home, and in seasonal operations in the country, is difficult. Welfare work for children in the period between leaving school and entering the factory is therefore important in order to avoid vagabondage.

**Legislation**

The absolute minimum age below which children's work is prohibited in industry, without any reserve, is as follows:

- 10 years: China (boys), Hongkong, Hungary, Portugal, Spain; 12 years: South Africa, Argentina, Austria, Brazil (Sao Paulo), China (girls), Czechoslovakia, France, India, Italy, Japan, Lithuania, Luxembourg, Norway, Peru, Hungary; 13 years: Germany, Chile, Finland, New Brunswick, New South Wales, New Zealand, Queensland, South Australia, Sweden (boys); 14 years: Belgium, Brazil (federal district), Bulgaria, Ceylon, Chile, Cuba, Denmark, Estonia, Great Britain, Greece, Holland,
Irish Free State, Latvia, Manitoba (boys), Nova Scotia, Ontario, Panama, Quebec, Saskatchewan (boys); Sweden (girls), Switzerland, Tasmania, Victoria, Western Australia (boys), Yugoslavia; 15 years: Alberta, British Columbia, Guer- tenstein, Martinawa (girls), Poland, Saska- thewan, Western Australia (girls).

As regards mines see article "Mines (Hygiene in")

In the United States each State has its own laws. It is therefore difficult to sum up the arrangements in a few lines. Suffice it to say that, with the exception of six States, the permission of admission into factories is fourteen years and six States have fixed fifteen years and even older still. (For details see Industrial and Labour Information (published weekly by the International Labour Office), 8 June 1925, p. 51.) As has been mentioned above, American legislation tends and, rightly, to go on raising the age of allowing juveniles to enter factories.

As regards the admission of juveniles into commerce, it can be said that, speaking generally, the question is very complicated and that it would be better to refer to the legislative texts.

With some legislatures the age of admission of children is made to depend on the occupational risk. Thus, for example, a law which admits children to industrial work at fourteen years of age, prohibits the employment of juveniles of less than fifteen years at a considerable number of unhealthy operations. All work in abatoirs, knackers' yards, and gut works, is prohibited to juveniles of less than sixteen years. All work near transmission machinery, and at machinery cleaning and repairs, is forbidden to adolescents of less than seventeen years; nor are adolescents of less than seventeen years admitted to work near machines in motion; while adolescents of less than eighteen years are excluded from factories and workshops where explosives are handled.

Another law excludes adolescents of less than sixteen years from work on Sundays and general holidays; those of less than seventeen years from any overtime work; those of less than eighteen years from night work and from any shift of workmen employed for more than four consecutive hours without a rest pause; from exhausting work, such as loading and unloading ships or working cranes; in quarries; as mechanics or chauffeurs; from oiling and cleaning machines in motion; from handling driving belts; from work with circular saws; from founding metals and glass-blowing; from carrying incandescent materials; and from selling distilled alcoholic drinks.

Young persons of less than fifteen years or, according to the country, of less than sixteen, seventeen or even eighteen years, are excluded from certain unhealthy, dangerous, or heavy processes. There may be mentioned, among others, the silvering of mirrors with mercury; work with chromium; vulcanisation by sulphide of carbon; the manipulation of lead compounds and lead derivatives; the pottery industry; brassfoundry work, and accumulator factories or very dusty operations; or operations which give off vapours, poisonous gases, fumes, or steam, entailing work in a humid atmosphere; or operations with exposure to high temperatures, or to a warm damp atmosphere, or to excessive fatigue from carrying weights and loads (see article "Women's Work"), or to dangers of poisoning by lead, arsenic, or phosphorus.

This exclusion also extends to all work or operations which involve any hazard from vapours or injurious dust, unless the dust or vapours are removed by mechanical means.

Night work is prohibited for children under fifteen years in: Italy, Japan, Rumania, and in special cases in Denmark and Germany; for those under sixteen years in: Argentina, Belgium, New Zealand, South Africa, Spain, United States; under seventeen years in: Holland, Poland, and, in special cases, Norway; under eighteen years in: Denmark, France, Great Britain, Norway, Sao Paulo (Brazil), Sweden and Switzerland.

In France, in certain cases the law allows the admission of children aged thirteen years in Germany and Spain those aged fourteen years.

As regards the conditions of admission for children and young persons to street stalls, see article "Women's Work".

The measures which have been dealt with up to the present have been made

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1 The Act of 7 Dec. 1996 contains a clause which has a very general bearing, for it applies to "workmen and clerks employed in industrial or commercial concern of whatever kind". The Government has the power to prohibit by a public administrative order the employment of juveniles and women under eighteen years in any work in which their health or morals may be endangered.
the subject of International Conventions or Recommendations.

The Washington Convention (1919) fixed the admission of juveniles to industrial work at fourteen years, except in the case of businesses in which are employed only members of the same family. Some exceptions are made in the case of Japan and India (Articles 5 and 6).

By April 1928 this Convention had been ratified by the following States: Belgium, Bulgaria, Chile, Czechoslovakia, Denmark, Estonia, Great Britain, Greece, Ireland, Japan, Latvia, Poland, Rumania, Switzerland, and Yugoslavia.

The same Conference approved a Draft Convention prohibiting the employment during the night of children under eighteen years, with an exception for children over sixteen who are employed in certain industries, e.g., steel and iron works, gunpowder, paper-mills, sugar refineries, and the reduction of gold ore, on work which, by reason of its nature, must necessarily be continued day and night. The term "night" signifies a period of at least eleven consecutive hours, including the interval passed between 10 o'clock at night and 5 o'clock in the morning (for details see the Convention).

By April 1928, this Convention had been ratified by the following States: Austria, Belgium, Bulgaria, Chile, Denmark, Estonia, France, Great Britain, Greece, Holland, India, Ireland, Italy, Latvia, Poland, Rumania, Switzerland, and Yugoslavia.

A Conference at Genoa adopted a proposal which fixed the minimum age for the admission of juveniles to work at sea; that of Geneva in 1921 adopted a Convention fixing the age of admission of young persons to work as trimmers or stokers on board ships, as well as an agreement relating to compulsory medical examination of juveniles and young persons employed on board ships (see article "Seamen").

The 1921 Geneva Conference adopted a Convention relating to the age of admission of children to work in agriculture and a Recommendation relating to night work of children and young persons in agriculture (see article "Agricultural Labourers" and the texts of these Conventions).

Several laws require the examination, free of expense, of adolescents by a doctor nominated by the factory inspector, in order to decide that the work on which the adolescent is employed does not exceed his physical strength and is not injurious to his development.

In Belgium one of the chief duties of the factory medical service has been putting into practice the periodical medical supervision of adolescents at work.

This supervision includes essentially: a medical examination of the adolescent during the first month he is admitted to work; an annual re-examination; and extra re-examination for individuals of delicate health; an obligation placed on the employer to pay attention to measures considered necessary by the inspecting doctor with a view to safeguarding the physical development of those delicate in health; refusal to admit to work adolescents who decline to submit to health supervision; and the adjustment of each child to work for which he is physically fitted.

Supervision of the health of adolescents at work was laid down by the Royal Decree of 1 June 1920. A Ministerial Order determines the method of conducting this supervision (30 October 1920), and decides as to the sort of individuals to be examined and the kind of medical form to be used.

Among the medical investigations may be mentioned points relating to the skeleton — the vertebral column, thorax, pelvis, and limbs; to the mouth — malformations, teeth and glands; to the nose — malformations and adenoids; hernias; and nervous disorders. The forms used in the investigation contain also columns for annual records from thirteen to eighteen years, for acuteness of vision, acuteness of hearing, height, weight and chest measurement.

A memorandum drawn up by the English medical inspector of factories for certifying surgeons may be mentioned here. It is also interesting to mention the instructions drawn up by the Industrial Hygiene Service of the Factory Department of New York for young girls at work. These instructions include advice regarding food, beverages, clothing, spare time, personal cleanliness, sleep, care of the teeth, sexual hygiene (menstruations), constipation, colds and headaches. Similar instructions have also been prepared for young girls employed in particular industries, such as laundries.

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Chlorates

Spanish: Cloratos.

Under this designation are grouped facts concerning chlorates of potassium, sodium, and ammonium, since injuries caused by these products differ only by a mild degree in intensity.

Chlorate of potassium, \( \text{KClO}_3 \), is obtained by bubbling an excess of chlorine through a solution of caustic potash, or by heating a solution of potassium hypochlorite. Up till recently it was prepared commercially by bubbling chlorine through milk of lime. The chloride of lime formed was decomposed, after filtration, by a measured quantity of potassium chloride. The potassium chloride, which is not easily soluble, was separated by evaporation and purified by recrystallisation. By this method much of the chlorine was lost. It is now produced by electrolysis of a warm concentrated alkaline solution of chloride of potassium, to which is added hydrate or bichromate of potassium. The purification of the chloride is done by dissolving it in warm water, adding a little barium chloride to precipitate the chromate, and then filtering it to remove the iron as well. The crystallised chloride is separated by cooling. The bichromate can be replaced with advantage by chloride of cerium. Chlorate of sodium is a secondary product in the manufacture of caustic soda by the electrolytic method.

Potassium chlorate is used in the manufacture of matches, especially in Swedish ones, fireworks, explosive capsules, and some explosive powders; in dyeing, in order to oxidise certain substances which produce aniline black—here the oxidising effect is accelerated by means of catalysts, such as salts of copper, and vanadium. Chlorate of sodium, which is less costly, is being used more and more to replace it.

Sodium chlorate, as well as the perchlorate, are products from the electrolytic process analogous to that used for salts of potassium (see that article).

Ammonium chlorate, \( \text{NH}_4\text{ClO}_3 \), is prepared by neutralising a solution of hydrochloric acid with ammonia or ammonium carbonate, or by precipitating a solution of calcium chloride by ammonium carbonate, or by mixing a solution of ammonium tartrate with potassium chlorate. The crystals melt at 102° C. with an explosion. Exposure to yellow light in time also causes an explosion. For perchlorates, see article "Explosives".

The chlorates, and potassium chlorate in particular, have caused quite a large number of accidental poisonings, but they are not very active substances. The sodium salt is still less active. In large quantity and by ingestion, which does not occur in industry, they exert a poisonous action due to their violent oxidising properties, and to their forming methaemoglobin in the blood with destruction of the red blood cells. In vitro blood to which potassium chlorate has been added gives in the spectroscopic bands characteristic of methaemoglobin. The clinical picture is characterised by serious jaundice, anaemia, and coma. The salts are rapidly eliminated in the urine and are found in the saliva, sweat, and milk.

When heated, chlorates set free oxygen; when exposed to blows or friction, they set fire to various combustible bodies, such as sulphur, phosphorus, sulphide of antimony; hence arises danger from explosion. Strong acids, and, in particular, concentrated sulphuric acid, cause with chlorates an explosion due to the formation of the explosive dioxide of chlorine.

Another danger, and perhaps the most important to bear in mind, is that, when working with chlorates, the clothing may become impregnated, and then burst into flames very easily; whence arises danger from burns. In powder factories the manipulation of chlorates certainly sets free dust in large quantities, but sickness definitely due to this substance has not been observed (Courtois-Suffit).

In the German factories the inhalation of dust containing chlorates appears to have caused disorders of nutrition and of the respiratory apparatus, which, however, seem rather to be due to impurities in the chlorates, inasmuch as these lesions, although arising from the product obtained


See also Bibliography of Industrial Hygiene, published quarterly by the International Labour Office.

The drawings on p. 426 are taken from Pamphlet No. 136, published by the Bureau of Women in Industry, New York.

Drs. Fuss (Geneva).

See The drawings on p. 426 are taken from Pamphlet No. 136, published by the Bureau of Women in Industry, New York.
electrolytically, were not caused when products were obtained by other methods.

Cases of irritation, erythema of the skin, and even of sores situated on the fingers, accompanied by oedema of the face, are fairly common. Oppenheim reports twenty-six cases of dermatitis due to chlorates made electrolytically. Egli mentions some cases of explosions in chemical laboratories due to experiments made according to inaccurate instructions given in chemistry textbooks.

Montesano reported some cases of eczema among munition factory workers. Ranelleti, in a factory for producing chlorate of soda by the electrolytic process, found that 56.5 per cent. of the workers had ulcerations, and 15.7 per cent. had perforation of the nasal septum caused by bichromate of potassium used in electrolytic operations. One case of ulceration by chlorate was compensated in Switzerland in 1924.

It may be noted that hydrogen comes off from electrolytic tanks into the air of workrooms and carries with it small quantities of potassium chloride; in time the roofs of the factory are covered with a thin white layer of this salt.

It is advisable to ventilate the workshops thoroughly; to make the floor impermeable; to close all openings on to public streets; to set up the departments for crystallisation, crushing and packing in separate rooms; not to use wooden receptacles; to isolate vats from the ground by means of porcelain bowls containing oil; to isolate the floor of the workshop so that the workmen can touch the vats and clean the electrodes and yet be protected against electric shock; to have the workmen medically examined on engagement and periodically thereafter if solutions of chlorides with bichromate are used; to distribute working clothing resistant to fire; to clean the clothing frequently; to ensure first-aid treatment for all cases of burns of the skin and mucous membranes; to discharge into the drains only liquids abundantly diluted with water.

Injuries caused by chlorates of sodium and potassium are compensated by Swiss, Japanese and Finnish laws (see also article "Occupational Diseases: Compensation").

Concerning hygienic measures, see article "Chemical Trades".

### Chlorates (Alkaline)


In this article the chlorides of sodium, potassium, ammonium, and calcium will be examined.

Potassium chloride, KCl, is found in very large quantities in the form of sylvinite in the deposits of Stassfurt, or mixed with magnesium chloride in carnallite. It is used in agriculture as a manure, in the preparation of other salts, in the electrolytic manufacture of caustic potash and of nitrate of potassium by the conversion method, etc.

Chloride of sodium, NaCl, well known under the name of "salt", used for the preparation of other artificial sodium salts, is found in the sea water (which contains only about 3 per cent.) or in the solid form in rocks (rock salt). It is extracted by evaporating sea water in saltpits by the heat of the sun. In cold countries sea water is frozen in winter, ice being thus obtained almost salt free: the process is repeated until a concentrated solution is obtained which is thus evaporated under direct fire in a large boiler or by a method analogous to that used at Stassfurt. In Germany the salt water is pumped up and sent in the form of fine spray on to piles of wood in bundles. Evaporation is favoured by the wind or sun; but this method loses too much salt (20-30 per cent. in the air).

Salt is used in the manufacture of the carbonate, sulphate and hydrate of sodium, hydrochloric acid; for the reduction of minerals; with hypochlorite of calcium for bleaching; in factories for cementation and for hardening files; in the manufacture of ice; in the freezing industry; for flavouring animal and vegetable products; for feeding cattle; in the manufacture of colouring matters; in pottery, textile manufacture, manufacture of paper, soap, refining of oils, etc.

Ammonium chloride, NH₄Cl, or sal ammoniac, is prepared to-day with the amnoniacal waters from gas lighting. Effort is made to obtain it by decomposing ammonium sulphate with potassium chlorate. Dissociation into ammonia and hydrochloric acid easily takes place in the presence of steam at a temperature below that of dissociation (350° C.). Ammonium chloride is used especially by solderers because, with this material, the hydrochloric acid which is set free dissolves the oxides on the surface of the metal; in colour factories, in textile printing, etc.
Calcium chloride is in nature united with magnesium chloride (tachydrite). It is obtained in great abundance as a residue in different industrial processes; for example, in the manufacture of ammoniacal soda. It is used as a dehydrator for drying gases (especially those of blast furnaces), but it cannot be used for ammoniacal gases because it combines with them; for dressing cloth; for preparing the brine (artificial ice factories), etc.

These substances have no great importance from the point of view of industrial hygiene. It should be borne in mind, however, that a source of danger may be present in the impurities they contain; hydrocyanic acid, arsenic, sulphuretted hydrogen gas, etc., and that electrolytic preparation of the chlorides may be the cause of mercurial poisoning when mercury is used in the baths. In this industry another danger is represented by the explosion of the mixture of hydrogen and chlorine if, owing to faulty supervision, these two gases come off in unduly large quantities. Work with salt is certainly very arduous, as is also that of concentrating the salt water; the hot and humid atmosphere represents a danger.

The toxic action of these chlorides depends essentially on the nature of the metal in combination; chloride of sodium is harmless (save in rare exceptional cases); that of potassium in large doses acts like a salt of potassium, that is, as a muscular poison.

The manufacture of Javel water (alkaline chlorides) presents the same risks as does that of chlorine (see that article) when the process of chlorine acting on a solution of caustic soda is employed.

Muller has examined 165 men employed in grinding and packing chloride of sodium, in 45 of whom he found nasal catarrh, in 45 perforation of the nasal septum, and in 9 recent ulceration. Further, he noted digestive disturbances and skin lesions attributable to the action of the hypochlorites.

An enquiry made in Russia in 1924 among 3,000 workers in the salt mines showed that a large number of cases of localised dermatitis occurred on the hands and feet.

The use of salt in the food industry (for flavouring) is also the cause of dermatitis, which occurs in those extracting and crushed the salt as well as in hemp spinners. An acne with redness and oedema of the face, the eyelids and borders of the ears has been found in table salt refiners (in workmen engaged in drying and stoving). Collis found pustular dermatitis in women employed in salting herrings. The lesion was situated at the internal surface of the forearm in those packing the herrings in barrels. Deep painful ulcers were also found at the end of the fingers, on the dorsal aspect of the fingers and hand and this form of ulcer affected mainly the young people gutting the fish. Catarrh of the respiratory tract is said to be frequent among workpeople engaged in concentrating the salt water.

The workrooms should be ventilated and local exhaust ventilation applied where dust arises (in crushing, packing, etc.).

Lesions due to chlorides (diseases of the skin) are compulsorily notifiable in Russia. Eczemas and dermatitis occurring in salt work, etc. are also notifiable in the Netherlands.

For legislation, see articles "Chemical Trades" and "Chorates".

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**Chlorine**

French: Chloré. — German: Chlör. —
Italian and Spanish: Cloro.

**CHEMISTRY**

At ordinary temperature and pressure chlorine (symb. Cl) is a heavy gas (sp. gr. = 2.9), greenish-yellow in colour, with an irritating and suffocating smell, very soluble in various liquids (carbon tetrachloride, tetra and pentachlorethane, chlorine of sulphuryl), etc.

A litre of water at 15° C. dissolves about 2.5 litres of the gas; the maximum of solubility is obtained at 8° C. Wood charcoal readily absorbs it. Chlorine at ordinary temperature combines with the majority of the elements. It combines directly with the metalloids (except fluorine, oxygen, nitrogen and the inert gases) with evolution of heat and light. It reacts readily with metals; gold and platinum dissolve in chlorine water to form chlorides. Its great affinity for hydrogen is very characteristic. It destroys numerous organic matters in order to combine with the hydrogen in them, and in the presence of water it acts as an oxydiser — a fact which justifies its use as a disinfectant and deodoriser.

Chlorine similarly attacks certain metallic oxides. With alkalis, provided it is not in excess, it yields a mixture of hypochlorite and chloride (Eau de Javel); in the contrary case, a mixture of chloride and chlorite. Reacting on slaked lime it produces calcium chloride. (See also articles "Chlorides (Alkaline) and "Lime"). With ammonia it forms very readily white fumes of chloride of ammonium. By making chlorine act on hydro-car-
forms, substitution or chlorinated additive products are obtained, such as chloroform (CHCl₃), carbon tetrachloride (CCl₄), etc. With carbon monoxide in presence of wood charcoal oxychloride of carbon (CO Cl) or phosgene gas is formed.

- Chlorine can be liquefied at a temperature of 21°C and a pressure of 6 or 8 atm. (by means of steel pumps lubricated with strong sulphuric acid) or by cooling to -49°C at ordinary pressure by means of sulphuric acid refrigerating machines. Liquefied chlorine is a dull yellowish-green liquid having a specific gravity of 1.42 at 15°C, boiling at -33.6°C, and solidifying at -102.6°C in clear yellow crystals. It is put on the market in steel cylinders. The receptacles ought to be able to resist a pressure of 22 atm. (the pressure exercised by the liquefied chlorine is from 6 to 7 atm. at 20°C), and they ought not to contain more than 1 kg. of liquid per 0.8 litre of capacity.

**MANUFACTURE**

(1) Electrolytic Manufacture

This is to-day almost the sole method for the industrial preparation of chlorine, either aqueous solutions of alkaline chlorides or of the fused chlorides being electrolysed.

(a) In the electrolysis of aqueous solutions of alkaline chlorides, sodium or potassium chlorides are used, and the chlorine is recovered as a by-product in the electrolytic manufacture of caustic soda (or potash). In such electrolysis one of these substances and hydrogen is formed at the cathode and chlorine at the anode. These are prevented by appropriate devices from combining with one another, and they are recovered separately. Chlorine is put on the market after having been liquefied by pressure. The hydrogen is generally lost, although, in certain processes, it is combined with chlorine, yielding hydrochloric acid.

The processes used are classed under four categories — electrolytic cells with a porous partition or diaphragm, with mercury, with a bell (without diaphragm or mercury), and with a diaphragm and circulation.

In the first process the diaphragms are usually made of vegetable parchment, asbestos cloth, treated with silicate or coated with kaolin, or asbestos plaques dipped in a solution of gelatine to which bichromate of potash has been added, etc.

In the mercury process the cathode consists of mercury so placed that the sodium formed in the course of the electrolysis is immediately absorbed, forming an amalgam, while chlorine is given off freely at the anode. The amalgam of sodium thereafter decomposed by the water gives soda and hydrogen regenerating the mercury. The Castner apparatus consists essentially of a trough, the bottom of which is covered with a thin layer of mercury and divided into three compartments by partitions which do not reach to the bottom. The end compartments each contain the carbon anode and receive the solution to be electrolysed. The cathode is in the central compartment where the water circulates. As the trough is agitated, the mercury circulates between the compartments. The amalgam is formed with disengagement of chlorine in the end compartments, and then becomes decomposed in the central one, forming caustic soda, evolving hydrogen and regenerating the mercury. In another apparatus, the Kellner, the mercury is forced to move continuously from side to side by compressed air (monte-jus). Solvay effects the decomposition of the amalgam in a cell distinct from that of the electrolysis apparatus. In another type of apparatus, regeneration of the chloride of sodium is prevented by placing a concentrated solution between the brine at the anode and the mercury at the cathode.

In the bell process, the typical form is represented by a kind of bell containing the anode, mixture of the products issuing at the two poles being prevented owing to the superior specific gravity of layers of liquid rich in alkali.

The last procedure allows more concentrated solutions of form to caustic soda by utilising, as in the bell process, circulation of the brine towards the cathode.

(b) Electrolysis of the fused chlorides is a process of manufacture less employed than the former, and serves especially for obtaining metals, such as sodium, calcium and magnesium, chlorine being a by-product. Generally, chloride of sodium, mixed with chloride of potassium and chloride of calcium, is electrolysed in an apparatus of which several types are known (Grabau, Borchers, Graetzel, etc.).

The chlorine obtained in these different ways is aspirated into an apparatus where it is generally compressed before being placed on the market.

(2) Preparation by Decomposing Hydrochloric Acid

(a) The manganese dioxide process is only used on premises where relatively small quantities of chlorine are needed for use in the factory.
ganese dioxide being relatively costly, this method is becoming less and less important. The Weldon process permits utilisation of the residue of chloride of manganese. The mud remaining in the chlorine generating still is first treated by carbonate of lime, then led into towers, where it is submitted to the action of milk of lime, a current of air, and steam. Manganese of calcium is formed, which is used instead of manganese dioxide. The chloride of manganese formed is treated anew, as described, and the process is repeated.

b) The principle of the process utilising the oxygen of the air consists in passing a mixture of air and gaseous hydrochloric acid over a catalyst. The Deacon-Hurter process, generally employed, consists in purifying and drying the gases coming from the saltcake furnaces. This purification consists in deposition of the dust and elimination of matters such as arsenic and sulphuric acid, which rapidly destroy the power of the catalyst. Further, the sulphuric acid is reduced to sulphurous anhydride, which converts the chlorine into hydrochloric acid. The purified and dried gases pass then to a superheater (at a temperature up to 450° C.) and then into a decomposer—an apparatus of cylindrical form, where the gases arriving at the periphery traverse an annular layer of the catalyst, and pass away through a central tube. These gases, which then contain, besides chlorine, water vapour, hydrochloric acid, nitrogen, etc., next pass through a purifying apparatus made up of a series of towers and plate columns. The solid chloride of lime is prepared by drying the chlorine in towers through which sulphuric acid trickles.

3. The Preparation of Chlorine by Decomposition of the Chlorides takes place in Several Ways

(a) Chloride of soda mixed with iron sulphate and calcined in a current of air yields chlorine. This method is used especially in the treatment of copper ores by the wet method.

(b) Ammonium chloride and calcium chloride, residual products in the manufacture of soda by the Solvay process, contain chlorine which is extracted by different methods (Mons, Solvay, Lye, etc.). In the last named, starting with calcium chloride and by double decomposition with lead nitrate lead chloride is obtained, which, when electrolysed, yields chlorine. The nitrate of calcium and residual lead serve to regenerate the lead nitrate.

Chloride of magnesium, which exists in abundance in the Stassfurth mines, can also yield chlorine. The chloride is dried by progressive heating (which yields a mixture of chloride and of oxychloride) and heated in a current of air furnishes chlorine.

Sources of Intoxication

(a) In the course of manufacture. — The risk of inhalation of chlorine in the form of gas is greater in the Weldon process which gives a more concentrated gas than in the Deacon process with its feebleer concentration. The danger is still less in the electrolytic processes because the modern installations prevent any escape. In this method of manufacture the dangerous process is especially the emptying of the electrolytic cells. In compressing the gas there is danger from the bursting of the receptacles and reservoirs containing the gas, whether pressed or liquefied.

In the Weldon process manganese poisoning has been reported from the use of manganese dioxide, especially in the process of grinding (Embden) and from the regeneration of chloride of manganese (Jaksch). In addition to this form of poisoning cases of poisoning by hydrochloric acid, chlorine fumes, and arsine wetted hydrogen gas, have been reported (in a factory for making washing powder).

The electrolytic process utilising mercury has been known to cause mercury poisoning. Besides poisoning by chlorine and hydrochloric acid, the Deacon process has caused poisoning from sulphur dioxide. This hydrochloric acid, it should be remembered, contains, as impurities, arsenic, sulphuric acid and sometimes nitric acid.

In all the electrolytic processes with alkaline chlorides the workpeople are exposed to the action (generally local) of caustic alkalis.

(b) In the course of the use of liquid chlorine or of operations which liberate the gas. — Chlorine is used in a great number of industrial processes.

Chemical industry: manufacture of hydrochlorites (Javel Water, Labarraque's solution), chloride of calcium, chlorates (of potassium and sodium) and perchlorates; manufacture of inorganic chlorine compounds: tri-, penta- and oxy-chloride of phosphorus; chloride and tetrachloride of sulphur; chloride of zinc, and of nitrogen; of synthetic hydrochloric acid (liquid chlorine, etc.); manufacture of organic chlorine compounds: chloride of
methyl, methylene, ethyl, carbon tetrachloride, mono-chloro-acetic acid, chloral, chloroform, chlorobenzol and other chlorine derivatives of benzene, and its homologues, etc.; manufacture of ferrocyanide of potassium, of iodine and bromine, of caustic soda by the electrolytic process; manufacture of asphyxiating and lachrymatory gases: chloro- acetate of ethyl, chloracetone, chloride of benzyl, chlorofomiate of trichlor-methyl, phosgene, chloride of cyanogen, etc.

**Manufacture of colouring matters:**

A great number of initial substances and certain chlorinated colouring matters.

Use of chlorine (in gaseous or liquid form) and of chlorinated substances for *decolorising* (bleaching, decolorising paper and textile fabrics); manufacture of shoddy; obtaining patterns on cotton cloth.

**Metallurgy of gold (separation of gold from silver).**

*Tinning industry:* retinning (Goldschmidt process); use of *aqua regia* (formation of nascent chlorine), of chlorinated substances as disinfectants, deodorants (e.g. in the purification of water), etc.

Chlorine vapour is also detectable in submarines (see that article).

**Toxicity**

According to Lehmann and Binz, chlorine has an irritating action on the mucous membranes (ocular, nasal and respiratory) as well as on the skin (action on the albuminoid substances and the epithelium, which it breaks up, with formation of chlorine compounds) and a general narcotic action when introduced into the general circulation. This paralysing action is denied by some writers (Jaksch, Kobert). Whether it be so or not, the mechanism is also explained differently because, according to some authorities on inhalation, free chlorine is at once changed into hydrochloric acid on reaching the mucous membranes and acts as such; while others (Cameron, Binz) believe that the chlorine remains free, and others again are of opinion that it changes into oxygenated compounds on reaching the mucous membranes and exerts its action in that manner.

The channel of absorption is through the respiratory tract.

According to Lehmann, a proportion of 0.001 mg. per litre is injurious to man; one of 0.003 mg. has a definitely irritating action; one of 0.003 to 0.004 mg. can be borne for some time; 0.005 mg. represents a maximal dose which can only be borne for a brief period; and 0.006 mg. is rapidly fatal bringing about remarkable respiratory lesions. Lehmann has demonstrated that the very smallest quantities of chlorine in the air are completely absorbed in the respiratory tract. He has even been able to prove experimentally that acclimatisation takes place — a fact already proved in the case of workpeople, in regard to whom acclimatisation takes place in several days or several weeks. (Certain workers can stand a dose four times as powerful as that poisonous to individuals not acclimatised: Lehmann, Ronzani).

Finally, an atmosphere containing more than some millionth parts of chlorine cannot be borne, as even traces in the atmosphere render stay in the room impossible.

**Statistics**

Among the numerous cases of poisoning by chlorine, it will suffice to refer only to those reported by factory inspectors or reported as industrial maladies. Often, however, such cases are not distinguished from those set up by hydrochloric acid, or even sulphur chloride.

**Bavaria.** — In 1919 7 cases were reported, in 1920 6, several in 1921, and 4 in 1922.

**Great Britain.** — Cases due to chlorine and hydrochloric acid numbered 8 in 1914, 3 in 1917, 4 in 1918, 9 in 1919, 8 in 1920, 3 in 1921, 11 in 1922, 48 in 1923-1925 and 44 in 1926-1928.

**Switzerland.** — Cases numbered 4 in 1915 (receiving compensation as accidents), of which 1 proved fatal; 16 in 1916; 1 in 1918; 2 in 1919 (including cases due to sulphur chloride); in 1920, 8 cases of poisoning and 3 of ulceration; in 1921, 5 cases of poisoning.

**Symptoms**

(a) *Acute intoxication.* — This rarely occurs, because small quantities of chlorine giving rise to an intense feeling of suffocation compel resort to fresh air. A dilution of 1 per 1,000,000 sets up a feeling of burning of the mucous membranes of the eyes and nose — even though the smell of chlorine is not itself perceptible. The phenomenon admitted by some writers of a reflex occlusion of the glottis which, though it entails difficulty of breathing, at the same time hinders inhalation of large quantities of vapour, is denied by other experts. When massive intoxication occurs death supervenes rapidly — in a few minutes — by pulmonary involvement, suffocation, and rapid collapse.
Usually acute intoxication commences with local irritation of the eyes (ichthy- 
mation), of the nose and throat (coryza), and of the buccal mucous membrane 
(excessive salivation). If the action on the ocular mucous membrane lasts 
some time or is very intense, slight or 
severe conjunctivitis results, as well as 
irritation of the cornea. The respira-
tory troubles are itselfed in air hunger, 
oppression, spasmodic cough, intense 
dyspnoea, bronchial catarrh, and 
sometimes lobular pneumonia. When 
exposure has been rather prolonged, or 
when the vapour has been highly 
concentrated, the patient has an 
irresistible cough with expectoration, 
sometimes bloodstained, spasm of the 
glotts, dyspnœa, chest pains, pulmo-
nary oedema, nausea and vomiting. 
The complexion is at first pale and then 
congested. The symptoms rapidly 
disappear on reaching fresh air or 
continue for some time if the poison 
remains. Death is caused by pulmo-
nary inflammation and oedema, with 
cyanoesis, small pulse, etc. If death 
does not occur, bronchitis, pneumonia 
and haemoptysis often supervene. 

The skin is affected by a feeling of 
burning, tickling, the formation of 
nodules, of vesicles, and sometimes of 
onopen sores.

(b) Chronic intoxication shows itself 
in chronic catarrh of the bronchi. 
Leymann has found among workpeople 
in a chlorine and calcium chloride 
factory a morbidity rate from respira-
tory disease of 17.8 per cent. (as against 
8.8 per cent. for ordinary workpeople). 
On the ocular mucous membrane there 
is dryness of the conjunctiva and 
painful inflammation of the cornea, and 
hyperplasia or palpebral eczema. Accli-
matisation would seem to take place in 
the case of workpeople who have to 
spend much time in an atmosphere 
containing chlorine. Among the general 
symptoms of chronic poisoning gastric 
troubles are reported — anorexia, 
wasting, anaemia with pallor of the 
face, and even precocious senility. 
Headache, vertigo, and sleeplessness 
have also been reported.

Teeth: The dental lesions are said 
to be less due to the chlorine vapour 
than to the hydrochloric acid (formed 
by the combination of the chlorine gas 
with the saliva) the action of which 
dissolves the dental substance. The 
flannel rags which the workers place 
between their teeth in the effort to 
prevent inhalation of the vapour play 
an injurious part. (See what is said 
of this in article " Nitric Acid ".) 

The lesions consist in a gradual 
destruction of all the dental substance 
without the production of any real 
inflammatory process. Vogt considers 
that the dental necrosis is analogous 
in its development to phosphorous 
necrosis of the jaw. The tooth becomes 
yellow and, after having been softened 
and deprived of its smoothness, finally 
crumbles away. The affected teeth 
are very sensitive to changes of tem-
perature, to mastication, and are liable 
to be the seat of excruciating pain. 
The crown of the tooth breaks up 
gradually until the whole tooth dis-
appears. The incisors are the most 
seriously affected as they are the most 
exposed.

Chloracne was first observed and 
described by Herxheimer in 1899 among 
workpeople manufacturing chlorine 
electrolytically; it is a dermatitis 
affecting persons exposed to the action 
of chlorine and its compounds.

Essentially the lesion takes the form 
of inflammatory changes more or less 
serious in the sebaceous glands, result-
ning in the formation of abscesses, with 
ultimately scarring and disturbance of 
nutrition. The following seem to be the 
main forms assumed (in order of 
increasing severity):

1. The acne begins with an acute 
erythema and swelling of the skin, 
followed by a chronic inflammation of 
the sebaceous glands. These do not 
become inflamed so much as merely 
swollen and show white comedones 
with blackened points. The condition 
is a simple folliculitis showing a round 
papule, with a central vesicle and a 
blackhead. The skin looks as though 
it were sprinkled with gunpowder 
fired from a gun at close quarters.

2. If the sebaceous glands become 
inflamed acne pustules develop with 
ulceration and formation of prominent 
violet scar tissue causing the skin to 
look as though it were transparent. 
Later tubercles develop.

3. This stage shows atheromatous 
cysts from the enlarged and inflamed 
glands.

4. Sometimes a definite and obsti-
nate furunculosis develops, which heals 
with the formation of numerous scars 
after cessation from work and after 
going through a special treatment. 
The skin then shows a horny and 
markedly pigmented appearance. The 
general health is more or less affected 
and among the symptoms noted 
are pallor and oedema of the face, 
headache, and generally speaking those 
cited above for the chronic form. The 
malady, although serious, is not fatal.
Lehmann refers to one fatal case due to pyaemia.

The acne is situated on the uncovered parts of the body (especially about the ears) and chiefly where any irritation of the skin has resulted from friction with clothing. Where the injurious action has gone on for a long time, a more serious form has been described affecting the covered parts of the body (groin and genital organs) due to impregnation of the clothing with the toxic substances, micturition performed without washing the hands, working with the legs wide apart (thus favouring access of the gas to these parts of the body), etc. The workers are said to be more affected by acne during hot weather because the clothing then is light, open, and saturated with sweat (Holtzmann).

Conveyance of chloracne to the families of workers has frequently been observed (from the wearing of working clothes or contact with them).

The pathogenesis of chloracne is still very obscure despite the numerous researches into its cause. Several substances have been suspected; chlorine (first accused by Herxheimer who subsequently absolved it); oxide of chlorine (Herxheimer); chlorobenzol (the same observer has thought that the acne might be due to passage of chlorinated phenol into the blood); tarry substances (so that according to Russig the condition is one of tar or paraffin eczema); chlorinated tar products or organic chlorine compounds given off in the electrolytic manufacture of chlorine by the action of this element on the carbon anode. Cases of acne have been observed by Bettmann among workers unpacking a hydrochloric acid tower constructed with tarred plates. Disappearance of cases has been observed by factory inspectors on substitution of carbon electrodes by magnetite in two factories for the electrolytic manufacture of chlorine. On the other hand, cases were noted by the inspectors in Baden in a sulphate of soda factory worked on the Hargreaves principle, where salt blocks had been previously dried on a metallic belt painted with tar. This stuck to the salt and during distillation gave rise to chlorinated tar products.

Further, chlorinated phenols have been suspected: hexachlorobenzol, hexachlorethylene, paranitro chlorobenzol, etc. (Leymann, Lehmann); indefinite chlorinated substances (Holtzmann) thinks that in the course of the manufacture of chlorine there is formed a chlorinated product, still liquid at high temperature or which goes over with the other gases, and on cooling remains fixed to the anode or to the receptacles. He does not consider free chlorine itself can give rise to dermatitis.

Fumouze has suspected hypochlorite of soda. In the electrolytic manufacture of chlorine the hydrogen carries with it particles of caustic soda which combine with the chlorine to make hypochlorite of soda. This in the nascent state attacks the skin and also the respiratory tract.

The view of Bettmann; Hallopeau, Jacquet, Fumouze, therefore, is that the acne is a direct external effect, while others (Lehmann, Herxheimer, Jacobi, Roth, Robert, etc.) consider it to be a dermatitis due to the elimination of the poison by way of the sebaceous glands.

Demonstration

Qualitatively the gas is demonstrated by its characteristic smell. Among characteristic reactions the following may be cited: removal of the colour from paper impregnated with indigo sulphate, bluish colour given to paper treated with starch and potassium iodide.

For a quantitative determination a definite quantity of the air to be analysed must be drawn through a solution of potassium iodide and the iodine set free must be titrated with hyposulphite of soda (Bunsen method). One cc. of a decinormal solution of the hyposulphite corresponds to 3-5 mgr. of chlorine. This reaction should be carried out in the absence of any nitrous fumes which also liberate iodine (Lehmann method).

Prophylaxis

1. First aid, when large quantities of chlorine have been inhaled (massive and acute poisoning), consists in carrying the patient to fresh air with inhalation of oxygen in severe cases.

Tonic stimulants (black coffee, camphorated oil injected subcutaneously, inhalation of amyl nitrite) should be administered to guard against the paralysing action of chlorine on the heart. For the irritating cough injections of morphine hydrochlorate, inhalation of steam, pulverised soda, etc. (Leymann, Lehmann); indefinite chlorinated substances (Holtzmann) thinks that in the course of the manufacture of chlorine there is formed a chlorinated product, still liquid at high temperature or which goes over with the other gases, and on cooling remains fixed to the anode or to the receptacles. He does not consider free chlorine itself can give rise to dermatitis.

An atmosphere charged with chlorine, although very injurious, is practically colourless, as it requires a proportion of chlorine above 4-5 per cent. (in volume) for the mixture with air to have a density sufficient to show the colour.
very dilute ammonia, or antichlorine (hyposulphite of soda), alcohol vapour (according to the recommendations of the Association of German Chemical Industries) and ether vapour should be given.

2. In the manufacture and manipulation of chlorine the airtight condition of the apparatus, pipes, etc. should be ensured and they should be connected up with exhaust ventilation so that a slight negative pressure is maintained in them. At the end of the series of apparatus some device must be installed for absorbing the remainder of the chlorine (towers filled with quicklime).

In the workrooms good ventilation should be supplied and should be tested from time to time.

Absorption or condensation of chlorine in excess; purification and deoxidation of the acid, liquid and other residues should be effected. The piping for carrying them away should be corrosion proof. The residues, even if they have been purified, should never be allowed to discharge into water courses.

In the workroom there should always be a carboy of ammonia in order to neutralise the effect of chlorine in case of sudden escape of the gas.

The soundness of the reservoirs and cylinders containing compressed or liquid chlorine should be assured. In the United States, for example, the use of liquid chlorine is regulated by the Inter-State Commerce Commission. The capacity of the receptacles may be from 100-150, 2,000 or 30,000 lbs. All the receptacles used for transport must be provided with valves melting at 70° C., a temperature for which the pressure is only a half or a quarter of the pressure for which the receptacle is tested. The breakages observed were always due to the presence of foreign bodies reacting with the chlorine.

The electrolytic manufacture of chlorine lends itself best to the application of all preventive measures. In particular, before proceeding with the cleaning of the electrolytic cells, the acid remaining in them should be neutralised with water containing lime. Special precautions should be taken in the cleaning of the cells. Proper preventive measures have, as a matter of fact, brought about the disappearance of chloracne in the electrolytic manufacture (replacing carbon electrodes with other substances such as magnetite).

Cleaning the Hargreaves towers, which has caused cases of acne in the manufacture of hydrochloric acid, should not be carried out in summer and the towers should be previously washed with milk of lime. The persons employed should be protected by overalls and caps impermeable to paraffin; they should be supplied with gloves and the exposed parts of the face and neck should be protected with vaseline. The clothing should fit closely at every point. Respirators should be worn while at work and a bath taken after work. Cases of chloracne will, nevertheless, it should be remembered, occur at times, despite such precautions.

In the Weldon process the apparatus should be air-tight and should not be opened until the chlorine has been completely removed.

All processes giving off manganese dust should be carried on under locally-applied exhaust ventilation, and this should especially apply to the grinding of the pyrolusite (manganese ore) and to the drying of the residual manganese chloride.

As soon as chlorine gas is perceptible in the air of the workroom, it should be quitted and the manager informed. Obvious escapes should be reported and repaired as quickly as possible. Oxygen breathing apparatus ready for immediate use should be at hand where there is risk of toxic gas. These self-contained breathing apparatus should be periodically tested to see that they are in proper order.

As regards individual preventive measures, overalls and breathing apparatus (Pilzner masks, for instance) should be worn after many trials to find out which were the most efficacious substances against the action of chlorine when used in masks, Kohn Abrest has shown that when the proportion by volume of chlorine in the air was about one in 1,000, absorbent cotton wool (neutral) dry or moistened with distilled water is sufficient to absorb them. The relative value of other substances tested (sodium carbonate, hyposulphite of soda, potassium iodide or a mixture of these substances) is not appreciable unless the proportion of chlorine by volume is above 1 per cent. Below this strength the different substances in question, when only a single aspiration of poisonous gas is made, have all about the same activity as regards chlorine.

Cleanliness (douche baths) are of use against chloracne. Dental lesions
can be lessened by avoiding the habit of keeping a piece of flannel between the teeth, but often only change of employment will avail to arrest the lesions formed. Use of alcaline solutions does not seem to have given the relief expected. Stumps should be extracted. Acid foods or those liable to ferment should be avoided. Careful dental toilet should be practised.

The workers should be informed of the risks, and notification of the appearance of skin lesions made to a medical man. Workpeople showing special susceptibility to skin lesions should not be employed.

LEGISLATION

Statutory Rules and Regulations (as e.g. in Great Britain) deal with the evolution of chlorine in certain industries (paper factories, for example) and especially in the chemical industries (see article "Chemical Trades"). Employment of women is prohibited in Argentina and in France and Holland in the manufacture of chlorine, and in Japan wherever the nature of the work exposes them to the escape of chlorine vapour. Young persons under sixteen years of age are excluded from chlorine factories in Belgium, and under eighteen in the Netherlands and Switzerland; boys under fifteen in Italy, under sixteen in Spain and Greece; girls under eighteen in Greece, and under twenty-one in Spain and Italy. Intoxication and lesions set up by chlorine are treated as accidents and receive compensation as such in Japan, Switzerland, Finland and Great Britain.

(See also article "Chlorine").

Chloroform
(Trichloromethane)

Chloroform (CH Cl₃) is a clear liquid with a peculiar smell and a sweetish taste and very unstable (under the influence of light it becomes transformed into chlorine, hydrochloric acid and carbon oxychloride). It boils at 61 to 62° C. Its specific gravity (at 15° C.) is 1.498 to 1.502.

It is obtained either by distilling a mixture of ethyl alcohol or acetone, water, and chloride of lime, by decomposing chloral with caustic potassium, or by making nascent hydrogen react on carbon tetrachloride.

It is used in the preparation of formic acid and particularly in the manu-

facture of certain alkaloids. Under the action of electric discharges it gives rise to the formation of certain of the highly chlorinated hydrocarbons.

The following risks connected with its manufacture may be mentioned: chlorine fumes, fumes of acetone and alcohol; the action of intermediate products and impurities, such as: amyl alcohol, ethyl chloride, aldehyde, allyl chloride, tetrachloromethane, phosgene, and chlorinated derivatives of propylc, butylc, and amylic acids.

Chloroform constitutes a poison of the nervous system. It is also a poison of the blood (hemoglobinemia, hemoglobinuria). Simpson (1847) discovered that consciousness might be completely suspended by the action of chloroform, and this fact explains its wide use as an anaesthetic in surgical practice and also as a local anaesthetic. Clinically chloroform causes phenomena of excitement followed by depression, loss of consciousness, and finally paralysis (of the heart and of the respiratory system). It also irritates the skin and mucous membranes, on which it gives rise to redness, caustication, and phlyctenia.

Medical literature only records one case of occupational poisoning, reported by Hofbauer, affecting a chemist's apprentice who in decanting chloroform was suddenly attacked by vertigo and headache and was unable to stand upright.

Chloroform appears on the Swiss list of substances injury from which entitles the victim to compensation similar to that granted in the case of accidents.

Chloropicrine

Chloropicrine, or nitro chloroform or nitrated chloroform, the formula of which is C₆N₂O₂Cl₃, is obtained by the action of nitric acid on chloral or, more usually, by treating picric acid with chloride of lime. It was used during the war as tear gas and was known as "emetic gas". According to Minkowski, it is the cause of pulmonary oedema. In France its use has been proposed for killing the cocoons in the silkworm nurseries.
Chromium and Chromates


Chromium

Chromium (symbol, Cr; atomic weight, 52.5; density, 6.8) is a shining white metal which melts at 1,950° C. It can be filed and polished, but cannot be drawn out or rolled on account of its great hardness. It is non-magnetic. The metal does not oxidise when exposed to the air at ordinary temperatures; it is attacked in the cold state by hydrochloric acid, but not by other acids.

Chromium forms three series of compounds, derived respectively from the protoxide of chromium, CrO; the sesquioxide, Cr₂O₃, giving, as basic oxides, chromous and chromic salts; and chromic anhydride, CrO₃, giving chromates.

The chief mineral of chromium, chromite, or chrome iron ore (Cr₂O₃·FeO) is a combination of the sesquioxide of chromium with the protoxide of iron; it is extensively distributed, but the number of deposits worked is limited, because only ore containing more than 40 per cent. of Cr₂O₃ is utilised. This ore contains variable quantities of silica, alumina, lime, manganese, and sometimes of copper, nickel, and cobalt. Chromium is also found in the form of crocoite or Siberian red lead, which is a chromate of lead.

Chromium is prepared by reducing, with charcoal in the electric furnace, sesquioxide of chromium obtained by the reduction of sodium chromate by means of sulphur or starch. Sodium chromate itself is derived from chrome iron ore (see further on).

This process does not give pure chromium, but a strongly carburetted alloy, the carbon of which can only be eliminated by reduction under an oxide brasse. It is still more easily obtained pure by the alumino-thermic process, in which chrome oxide is reduced by powder aluminium.

By reducing sesquioxide of chromium in the electric furnace in the presence of silica (gin process), a silicide is obtained which, when submitted to an oxidising fusion in the presence of the sesquioxide of chromium and lime, gives chromium and iron chrome with a very small quantity of carbon. By reducing the sesquioxide by means of aluminium, chromium free from carbon is obtained. Chemically pure chromium is prepared by electrolysis.

Uses

Pure chromium is very little used. It is made use of to prepare alloys, such as nickel-chromium with 10-20 per cent. and iron chrome with 20-30 per cent., and chromium wire, used as anodes for depositing chromium on articles. For this purpose, only electrolytic chromium is used, which is hard, but malleable. The process of chromating or plating with chromium by electrolysis is now carried out with perfection. It protects metals under conditions wherein plating by nickel and other protective layers is not satisfactory. But this plating is no more resistant to hydrochloric acid than are the alloys.

This industry is continually developing, and it is perhaps necessary to supervise closely the health of workers employed on it. (See article "Electro-plating").

Iron chrome is used to make very hard and very tenacious chrome steel used for files, tools, heads of shells, armour plating, and ball-bearings.

Chromic alone or mixed with tar, lime, and bauxite is employed for making linings and refractory bricks used in the construction of metallurgical furnaces.

Chromium is not poisonous in itself. Its manufacture does not present special dangers, except in the case of the preparation of alkaline chromates. However, during such enriching operations as roasting, the workmen appear to be affected with disorders due to the carbon monoxide which is given off during the process.

Derivatives of chromium.—Chromic acid, CrO₃, or the trioxide of chromium, usually known in the trade as chromic acid (French, Acide chromatique; German, Chromsäure; Spanish and Italian, Acido cromico), is prepared commercially by treating the chromate of barium or lead with sulphuric acid. It is also obtained by electrolysis of chromic sulphate. The commercial acid takes the form of red crystalline masses, or powder, still containing sulphuric acid or chromates. It is very corrosive, and is a strong oxidising agent used in the dye industry. However, a mixture of potassium bichromate and sulphuric acid is generally used instead of it.

With the alkaline chromates, chromic anhydride is the only compound which is directly toxic.

Chromates


The most important chromates are as follows:

Neutral chromate of potassium, K₂CrO₄, is theoretically derived from...
chromic acid, \( \text{H}_2\text{CrO}_4 \), and occurs in the form of yellow crystals; it is rarely used (for dyeing and the manufacture of inks).

Neutral chromate of sodium, \( \text{Na}_2\text{CrO}_4 \), and neutral chromate of ammonium are used in making green oxide of chromium. Bichromate of ammonium is used sometimes in photogravure and in making explosives.

**Bichromate of potash**, \( K_2\text{Cr}_2\text{O}_7 \), occurs in the form of anhydrous, inodorous, red crystals tinged with orange, melting at \( 400^\circ \text{C.} \) and soluble in cold water. Immediately after melting, the bichromate becomes decomposed into oxide of chromium, neutral chromate of potassium, and oxygen. It is frequently used as an oxidising agent with sulphuric acid, forming chromic mixture; it then becomes reduced to chromic sulphate. In industry chromic acid is recovered from this solution by means of electrolysis in a vessel with a diaphragm. Chromic acid forms at the anode and hydrogen at the cathode.

**Bichromate of soda** is very dilliquescent when hydrated; but, when heated to \( 200^\circ \text{C.} \), it becomes dehydrated and is no longer dilliquescent. It can then be melted and cast into plates; to-day it replaces potassium bichromate in most of its uses, for it is more soluble and less costly.

**COMMERCIAL PREPARATION**

Chromite is first "étonnée", that is to say, heated and then suddenly cooled so that it breaks into small pieces; it is then crushed and sifted.

The powder obtained is mixed with carbonate of soda and quicklime; then it is heated to about \( 1,200^\circ \text{C.} \) on the hearth of a reverberatory furnace in a forced draught. In this way chromate of sodium, carbonate of lime, and oxide of iron are obtained, only the first of these being soluble. The mass, after cooling and crushing, is treated with water in an apparatus fitted with agitators. The solution is helped by jets of steam. The addition of an excess of alkali helps the formation of chromate calcium, which passes into the filtered liquid through the filter press. This liquid is concentrated and then treated by sulphuric acid which changes the sodium chromate into bichromate. The sulphuric acid must be quite free of arsenic and oxide of nitrogen. The solution is concentrated over an open fire, and the sulphate of sodium, which is only slightly soluble, is precipitated. The crystals are extracted, drained, washed, and dried. If the concentration is increased to \( 60^\circ \text{B.} \), crystals of hydrated sodium bichromate are deposited in their turn. They are transformed into potassium bichromate by double decomposition with hot potassium chloride. Potassium bichromate can be prepared by electrolyzing a solution of sesquioxide of chromium in excess of potash. The chromite becomes changed into chromate and then into bichromate. By new processes using residuary sulphate of soda and baryta in place of lime, bichromates and caustic baryta are prepared simultaneously.

The oxide of chromium obtained as a residue is then used in making alizarine dye or in electric batteries. Bichromates can be made by mixing it with slaked lime.

Neutral chromate of lead in the natural state is crocoisite or Siberian red lead; when obtained artificially it is chrome yellow. It is prepared by precipitating a solution of acetate or nitrate of lead with bichromate or chromate of potassium or sodium. It can also be obtained by digesting carbonate or basic chloride of lead with an alkaline bichromate. The extract of bichromate obtained by boiling is washed, filtered, dried, crushed, sifted, and packed.

Basic chromate of lead, or chrome red, or cinnabar of chromium, is prepared by treating neutral chromate with an alkali. By mixing the two chromates in different proportions chrome orange is obtained.

In commerce these two products are rarely pure. They are found under fancy names mixed with other substances, the chief of which are lead sulphate, chalk, kaolin, and gypsum.

**USES**

Chromates and bichromates are used in a great many industrial operations, among which may be mentioned: the manufacture of chromium and its compounds, such as oxides, salts, and chrome alum; chrome colours (see later), the manufacture of coloured crayons; paper, wall-paper and linoleum; the preparation of colouring materials which require an oxidising agent, such as aniline greens and reds, and for the oxidation of anthracene into anthraquinone; the manufacture of colours from logwood, catechu, and red wood; the manufacture of inks; of aldehydes and numerous oxygenated organic products; in scientific laboratories for the preservation of tissues; for bleaching oils, fats and beeswax; for...
purifying alcohol (e.g. the French national carburetant); the manufacture of fuses and explosives with pyroxiline and ammonal; Swedish matches; as colours in dyeing, for printing especially; for frosting, enamelling and colouring glass, porcelain, earthenware, and stone ware; for chromium plating; for staining and polishing wooden articles; for rendering gelatines insoluble under the influence of light, used in the graphic arts of photography, photogravure, carbon process, zincolithography, and photo-engraving; for rendering paper and tissues impermeable; in the rubber industry, for the preparation of mixtures and artificial rubber, and making tyres; in tanning with chromium; in the accumulator industry for bichromate batteries; and in laboratories for chemical analysis.

Chrome colours are generally those compounds of chromium which have been mentioned above, because these compounds are all coloured. Yellow colours, with shades varying from greenish to red, passing through orange, have a basis of lead chromates; others are prepared by combining chromic acid or the alkaline carbonates with various metallic salts.

Green oxide of chromium is obtained by calcining chromate of ammonium or a mixture of chromates of soda and sal ammoniac. Other greens are obtained by the oxidation of the bichromate, yielding residuary salts of chromium, which are treated with carbonate of soda, calcined and washed. English greens are a mixture of chrome yellow and Prussian blue.

The preparation and handling of these products is associated with the same dangers as the use of chromates.

Numerous brown, blue, and black colours have a chrome basis; but they are not generally used. Chrome alum appears in the form of deep violet crystals and is prepared by reducing potassium bichromate in sulphuric solution by sulphurous gas or alcohol. It is formed also as a by-product in the aniline dye industry and generally during the oxidation of organic bodies by potassium bichromate.

It is used as a mordant in dyeing, for preserving gelatine, and in tanning.

**Sources of Danger**

Chromic acid and the alkaline chromates have a local caustic action, which is more pronounced in the case of bichromates.

This action affects the skin and mucous membranes, especially in the case of hot solutions. It is more pronounced for women than for men (Gerbis).

The injurious cause shows itself sometimes in the form of finely divided droplets, sometimes in the form of somewhat fine dust or of small crystals. The evaporation and boiling of solutions of chromates give rise to vapours which carry minute particles of caustic materials into the surrounding atmosphere: drying, grinding, transport, and packing of the product, on the other hand, cause dust, varying in amount according to the technique used.

In various countries the quantity of chromates set free, in the course of operations, into the atmosphere of a workplace has been investigated. Thus for example at 50 cm. above evaporating pans, containing solutions of bichromate of soda, there was found in the steam 0.084 mg. of chromate per cubic metre; at 45 cm. above another pan, 0.736 mg.; on a square metre of surface at 37 cm. from an evaporating pan during one hour, the quantity of chromate deposited was 23.81 mg.; at a distance of a metre it was 128.20 mg., and on the wall near the pan 205.11 mg. At 35 cm. from another pan the quantity of bichromate was 786.09 mg., and near a third pan 825.26 mg.

In 1918 Legge found 3.3 mg. and even 6.6 mg. of bichromate dust per cubic metre of air taken at the level of the mouth of a workman employed in crushing; and 0.5 mg. per cubic metre under the same conditions in the packing department.

The preparation of alkaline chromates and the regeneration of lye-wash of chromium may set up ulcers, eczema, and dermatitis; and also lesions of the respiratory mucous membranes and conjunctiva, and perforation of the nasal septum.

The use of alkaline chromates in industry (see the list already given) favours the development of ulcers on the hands and feet, of conjunctivitis, eczema, and dermatitis. Thus, for example, ulcers on the hands and feet are very frequent in chrome tanning, and in work on wooden articles. Eczema of long duration occurs in making Swedish matches. Eczema and ulcers occur in the textile industry. On the other hand, perforation of the septum is not frequent in making Swedish matches, chrome tanning, work on wooden articles, or the textile industry. It is a little more frequent in explosive factories; although in all these occupations the incidence of perforation is much less frequent than in the manufacture of chromates.
Plating with chromium (see article "Electroplating"), which for reasons of economy is more and more replacing nickel-plating, exposes the workman to dangers of lead poisoning and to injuries from chromium.

In processes with the galvanic bath, chromate lesions of the hands and nasal septum may occur when chrome vapour, which forms during the electrolysis, escapes from the confines of the bath.

Lead poisoning arises because certain fittings and armatures are of lead which under the action of chromic acid becomes changed into chromate of lead, the solubility of which in hydrochloric acid of 1 in 10 has been demonstrated. The production and use of chrome colours expose workmen to risk of lead poisoning rather than to danger from chromium; here the cotton fibre is first soaked in a solution of salts of lead, then treated by a solution of a chromate, and, finally, in order to obtain certain colours, by lime water. The use of cinnabar of chromium in the boot industry explains the few cases that occur of lead poisoning; more frequently lead poisoning occurs from the inhalation of chromic acid of lead, which is often, but wrongly, considered as harmless. Perforation of the nasal septum is very rare in this occupational group; it is to be attributed to traces of alkaline chromates contained in the colours used.

Some experts hold that in an advanced phase it is possible for absorption of chromates to exercise a fairly intense action on the digestive organs, affecting chiefly the liver with parenchymatous degeneration, and on the urinary tract, causing nephritis. The diagnosis is up to the present only an experimental finding, according to which the lesion would be set up by the elimination of chromates.

Undoubtedly vapour from boiling solutions containing particles of chromates in suspension are partly absorbed by the respiratory passages; but it has yet to be proved that these particles reach beyond the upper respiratory passages. It is, however, certain that these vapours cause acute dermatitis, which is more common among young persons or those predisposed to diseases of the skin.

Urban, Colden, Hansen, and Forschbach had an opportunity of studying the effect of chromates during an acute outbreak of non-industrial poisoning, which enabled them to collect facts concerning the pathogeny, the clinical symptoms, and the pathological anatomy of this intoxication. Happily a similar instance is only seen in industries where a workman absorbs a solution of chromates unawares. Nevertheless, the incidence of respiratory and digestive diseases is a little higher than in industry in general.

The above-mentioned experts observed nothing new as regards skin lesions. They were able to show that these lesions only occur when the skin is already damaged. The absorption is very rapid (one to two days), and in acute poisoning the kidney symptoms are very serious, including oliguria and even anuria, with cyanosis, shivering, oedema, coma, and vomiting. But these renal lesions have never been found among operatives and deserve to be more closely studied.

Ulcer of the duodenum analogous to the gastric ulcer caused by lead, observed by Rossle, may be caused by the probable localisation of the poison to the coeliac plexus.

Lesions of the eye take the form of affections of the retinal vessels, paleness of the optic nerve, and anisocoria (unequal pupils).

Kossa obtained experimentally a glycosuria of renal origin.

As regards individual susceptibility, it is found that the facts furnished by industry, especially as regards perforation of the nasal septum, point to the absence of any immunity.

Lehmann has taken up the study of chronic poisoning by chromates. By experimenting with cats for five days, and for three hours each day, he found that the inhalation of 8 mg. of chromates per 1,000 litres of air is sufficient to cause a caustic effect on the mucous membrane of the nasal septum, bronchial lesions, and death from pulmonary lesions. The experiments showed that danger arises chiefly from absorption of chromates by the respiratory passages.

It should also be borne in mind that workmen employed in mordant work, using hot solutions of bichromate and dilute nitric acid, are exposed to the vapours of nitrous fumes. Hamilton mentions a fatal case of a workman at a colour factory, following the burning of a mixture of lead chromate, Prussian blue, and ferrocyanide of potassium in the preparation of chrome green.

Statistics

Lesions due to chromates are certainly more common than is usually admitted. On perusing medical literature it is easy to find that questioning and periodical examination of workers employed in making and handling alkaline chromates show a very large number.
It was Cumming, of Glasgow, who, in 1827, first described ulceration among workers at a bichromate factory. Perhaps without knowing of the work of Cumming, Becourt and Chevallier in 1851 observed the same lesion among workers in chromates at a factory near Paris, and, replying to a list of questions sent out by these doctors, Isaac Tyson, of Baltimore, in 1852 confirmed the observation of his French colleagues.

Several cases of ulcers and perforation have been reported in Austria; thus, for example, in 1942 out of 60 workmen 15 were affected. In 1923 the use of a solution of chromates in a map-making institution caused some serious cases of eczema and conjunctivitis.

In Germany, several cases were noted in a factory open at this date at Griesheim; other cases were noted in 1894; in 1900 Hermann found that 70 per cent of the workmen examined suffered from ulcers and 48 per cent from perforation of the nasal septum.

Some cases of dermatitis with itching, papular eruptions, and pustules have been found in the department of fulling sheets which contained traces of bichromates; out of 262 fullers at Forst, 35 were affected.

The most carefully prepared data are certainly those supplied by Fischer, who gives the results of observations made in seven chromate factories during several years 1898 to 1900.

For every 100 full-time workers, these factories showed annual labour turnovers of 121.1, 325.5, 14.4, 316.5, 57.3, 27.1, and 73.35. These differences are explained by differences in plant and in technical organisation. Out of 700 workmen employed at these factories during seven years, 2,282 cases of sickness occurred. For every 100 cases of sickness there were: 8.82 cases of chrome ulcers, caustic effects and burns caused by acids and alkalis; 24.39 cases of ulcers of the nose; 7.76 cases of perforation of the nasal septum; 6.95 cases of eczema, dermatitis, and boils; this group accounted for a total of 11.91 cases with 176.36 days of sickness. Diseases of the kidneys showed a rate of 0.07; nervous diseases, 1.77; diseases of the circulatory system, 0.42; respiratory diseases, 15.36; diseases of the digestive organs, 9.83; infectious diseases, 8.96; this group totalled 36.33 cases with 584.25 days of sickness.

Among 100 workmen there were 71.42 cases of perforation of the nasal septum; 16.56 had been affected before completing a year's work; 19.14 before one to five years' work; 18.28 before six to ten years' work; 13.42 before eleven to twenty years; 4 had a length of service of more than twenty years.

Out of 100 workmen dermatitis was due in 5.82 cases to burns by chromates; in 4.53 cases to caustic effects; in 7.77 cases to ulcers from chromates; and in 10.35 cases to ulcers not well defined, including, however, those groups under the preceding denominations; 29.71 were cases of dermatitis from chromates; 5.18 were eczema and itch; 1.62 were simple dermatitis; 5.50 were boils; and 0.65 were lesions of the nails. Workers at aniline and chromate factories show an incidence of dermatitis much higher than occurs among workers in other chemical industries, such as acids and alkalis. As a matter of fact while the rate for derma-
Ulcers due to chromates are common among workers in industries involving the use of these substances. The incidence varies depending on the specific type of work. Among workers in sulphate and sulphuric works, the rate is 7.44 per cent. Among those in caustic alkalis, it is 9.40 per cent. Those in chlorine derivatives and permanganate have a rate of 14.38 per cent. Workers in chlorine derivates and permanganate have a rate of 32.24 per cent., while chromate workers have a rate of 31.49 per cent.

In 1910, Wolff found among 64 workers, 51 with ulcers due to chromates, of which 33 had been employed in the works for one to ten years and 19 from ten to twenty-one years. One worker had an existing ulceration of the nasal mucous membrane or the incipient stage of perforation; on the contrary, fully developed perforation affected 47 workers (73.44 per cent.).

In Prussia in 1912, it was noted that 90 per cent. of the workers in chromate works were affected by ulcers. Medical examination and careful selection of candidates led to a reduction of the incidence of these morbid conditions to 13.3 per cent. after a period of 1 to 35 months. Although the length of time of contact with the injurious products is a factor, the formation of a thick scar on the mucous membrane, once formed, inevitably prepares the way for the final lesion.

In a paint works at Merseburg, perforation of the septum was found in 1922 among 6 out of 8 workmen employed in mordanting with bichromate. In the Dusseldorf district, the manufacture of ferro-chrome caused ulcers and perforation of the septum.

In a very close examination made by Lehmann, this authority found among 65 workmen, of whom 52 had worked from one to twenty years, 16 cases of ulceration of the nasal mucous membrane, 26 of perforation of the septum after working from one to six months, and 7 cases after six to twelve months. The total was

![Fig. 37. — Ulcerations of the nasal septum due to chrome (after RANGETTI).](image)

cent. In 1913, 19 cases of perforation of the nasal septum were noticed among 90 workmen; in 1917, 11 cases among 11 workers; in 1918, 5 cases among 50; in 1919, several cases of eczema; in 1920, 12 cases were excluded because they were due to other causes (caustic alkalis). In 1921, several factories were closed, and the cases diminished. Nevertheless, out of 89 workmen, 7.86 per cent. had fully developed lesions, and 12.36 per cent. cicatrices which showed the existence of former lesions.

In 1922, an investigation made at a chrome and chromate factory at Mersebourg, dealing with a period of sixteen years and with 210 workmen (30-40 workmen a year), showed no change in the nasal septum in 48 persons; in 17 slight change; in 56 a distinct change, and in 61 a very marked change. The perforation found in 28 workers (13.3 per cent.) after a period of 1 to 35 months did not depend so much on the length of time of contact with the injurious products, as on the formation of a thick scar on the mucous membrane which, once formed, inevitably prepares the way for the final lesion.
of the nasal septum; 13 cases occurred in workers employed in the rooms for the preparation of lyes; 7 of the workers were employed at melting furnaces; 3 in the concentration rooms and 1 was employed as a grinder; in 1923, some cases of eczema were recorded as situated on the hands of tanners working with chrome were probably due to chrome-alum; in 1924, in an alkaline chromate factory there were 33 cases of lesions among 140 workers, of which 21 occurred in the lye department, 12 at the furnaces, and 2 in the grinding department.

In Bavaria, in 1920, 27 cases of perforation of the septum were reported, 14 cases of erosions, and 12 of ulcers of the skin; in 1922, 114 workers were examined and 7 cases of perforation of the septum and 6 of ulcers of the skin were found. In Württemberg 4 cases of ulceration and perforation of the nasal septum were reported in a dyeworks in 1922; and in 1921 1 case was reported at Hamburg and 2 in Saxony.

In Great Britain, Legge reported in 1902 that out of 176 workers 71.6 per cent. had perforation of the septum and 11.3 per cent. had ulceration of the nasal mucous membrane without perforation. He noted that some workers were more resistant than others. Mitchell, in 1916, had examined during three years 886 workers at chromate factories and only found 175 cases of ulcers, or 20 per cent.

Some important figures collected by the Department for the Medical Inspection of Factories gives for the period 1920-1926 the following number of ulcerations by chromates and by industry:

<table>
<thead>
<tr>
<th>Year</th>
<th>Bichromate factories</th>
<th>Dyeing and finishing</th>
<th>Tanning with chrome</th>
<th>Use of bichromates and other forms</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920</td>
<td>126</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>152</td>
</tr>
<tr>
<td>1921</td>
<td>29</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>57</td>
</tr>
<tr>
<td>1922</td>
<td>42</td>
<td>10</td>
<td>10</td>
<td>9</td>
<td>71</td>
</tr>
<tr>
<td>1923</td>
<td>45</td>
<td>9</td>
<td>12</td>
<td>18</td>
<td>76</td>
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<tr>
<td>1924</td>
<td>54</td>
<td>8</td>
<td>6</td>
<td>12</td>
<td>80</td>
</tr>
<tr>
<td>1925</td>
<td>55</td>
<td>2</td>
<td>6</td>
<td>12</td>
<td>75</td>
</tr>
<tr>
<td>1926</td>
<td>60</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

In 1923 the cases amounted to 58 (occupation not specified); 3 cases were caused by fluoride of chromic acid used as a mordant. In 1924 Dr. Hamilton, of Manchester, examined 26 chrome workers and found ulceration of the nasal mucous membrane in 11 cases and perforation of the septum in ten. In 1925 a case of irritation of the upper respiratory passages was reported in a worker employed in electro-plating metal articles with chromium. The in- ventor of the process showed perforation of the septum; and one worker had dermatitis as well as irritation of the nasal mucous membrane. It is considered that these lesions were due to vapours of chloride of chromic acid given off from the electrolytic bath. In 1926 out of 13 workers at chrome colour works there were found 10 cases of dermatitis and 11 cases of lesions of the mucous membranes. The establishment of periodical medical examination stopped these troubles.

In 1926 a case of dermatitis was noticed in a worker who printed the "blues" on paper with chromates (Parkhurst).

In 1928 the total number of cases which occurred amounted to 70. The Factory Inspection Department in Great Britain (Home Office) published in 1925 a small propaganda pamphlet on the subject of dermatitis in polishers of wood. These workers and particularly cabinet makers are affected with very painful cutaneous lesions due to the manipulation of colours (Bismarck brown, Van Dyck brown) and potassium bichromate.

In Italy several cases of lesions by chromates have been reported. Thus, for example, Ranellutti in 1919 found among 69 workers at a chlorate factory, handling potassium bichromate, ulceration of the nasal mucous membrane in 38, or 56.5 per cent., 7 of whom, or 15.7 per cent., showed perforation of the septum.

In Japan, injuries caused by chromates have, until recently, been unknown; but in 1927 several cases were reported to the competent authority; in consequence steps are being taken to arrange measures necessary for protection. In one factory which used chromates nearly half the personnel were affected by lesions due to these substances.

In the Netherlands, the Department of the Medical Inspection of Factories had knowledge of 11 cases of lesions caused by chromates.

In Russia, Wilensky (1924) found in a chromate factory 197 workers out of 278 affected with lesions, of whom 49 had ulcers of the nasal septum, 92 had a small perforation, 70 had a large perforation, 21 had granular pharyngitis, 15 atrophic pharyngitis, and 80 chronic pharyngitis. According to this expert, cases of pharyngitis should be compensated in the same way as other lesions by chromates. In 1927 Hellmann in the black section of a dyeworks, reported among 18 workers 5 cases of ulceration of the hands and forearms caused by a bichromate bath used as a mordant. These ulcerations were of slow development, relapsed frequently and left deep cicatrices. Education of workers and prophylactic measures taken by the management have much reduced this danger.

In Switzerland 22 cases of lesions by chromates were reported between 1918 and 1925 to the National Insurance Office.
In the United States, Ducatel, of Maryland, mentions that Bäer, of Baltimore, had seen 20 cases of lesions caused by chromates present in vapours. Gilman Thompson has reported a case of general poisoning.

**Pathology**

Lesions caused by chromates particularly affect the skin and mucous membranes.

On the skin, chiefly on that of the fingers, hands, upper limbs, face, and even the feet, in fact everywhere where the skin comes occasionally in contact with the injurious products ulcerations appear, round and sometimes oval, with red and thickened edges, and a necrotic base; in size their diameter averages from 3 to 10 mm. Clinically the lesion is very varied; it begins with dryness, roughness, and fissures which are very often aggravated by maceration.

According to the constitution of the individual one may find dermatitis of a vesicular or papular type with itching; it is difficult to cure. Sometimes the lesion appears as an eczema of a different kind with oedema and pains, often with an acute onset, especially when the workman has come in contact with hot solutions of bichromate. Among the sequelae of irritation of the skin, cases of septic granuloma have been reported.

The ulceration of the skin commences in an insidious manner, without pain, with loss of substance and slight signs of infiltration, which, however, may appear rapidly and suddenly and cause a round hard ulcer sometimes under a scab; if the patient is not looked after the ulcer may become deeper and deeper and reach the bone or a joint. Cases are known where the joint and the adjacent bone were laid bare. According to the constitution of the individual one may find dermatitis of a typical; it appears within a year and the bad habit of picking the nose and the irritant dust has exercised its action before the development of the ulcer. Rhinitis characterised by coryza and epistaxis is often observed. On examining the patient one finds, generally by chance, ulceration or even perforation of the nasal septum. These lesions occur generally without any interference with the nasal function and without any discomfort to the individual, the perforating process being practically painless. The ulcer is situated at the lower part of the septum, usually on the central part, corresponding to the organ of Jacobson, which is rudimentary in man, and is in the form of a round white spot, greyish looking like mud, which becomes deeper and deeper, involving the mucosa of the cartilage, finally leading to a perforation in the lower middle part, circular or oval in form, of pale pink colour without any sign of reaction. When a rhinitis or coryza prepares the ground and when the irritant dust has exercised its action for a long time, haemorrhages also occur, which bring about a peculiar state of the mucosa which Zuekerkandl calls "xanthosis". The mucosa is then yellowish and this stage appears shortly before the development of the ulcer.

The lesion may appear after as few as eight days but generally after some weeks, from six to eight. It does not affect the shape or the function of the nose; it does not exercise any injurious action on the respiratory or digestive apparatus. The general condition remains good. Healing is effected by cicatrization of the edges of the perforation.
tion, fairly soon if the workman gives up his work, less rapidly, from one to two months. He has continuous gripes. In some rare cases necrosis of the nasal bone has been reported.

In the case of the mouth the chromates may cause irritations with small yellowish ulcerations, which heal slowly. On the tonsils ulcers may occur which in some cases have been diagnosed as syphilitic chancre; pharyngitis, regarded as characteristic, has also been reported by Wilensky.

Ulceration of the palate which heals fairly quickly has also been noted.

Multiple lesions of the eyes may be present involving the eyelids, conjunctiva, and cornea, but they are not usually serious or characteristic. Keratitis caused by chromic acid is a typical affection which does not irritate the conjunctiva, but on the contrary damages the epithelium and the superficial layers of the cornea, which are coloured brown on the part not protected by the eyelids. The brown coloration is due to the formation of the insoluble oxide of chromium under the action of light. This lesion is persistent and causes diminution of vision. Vapours containing chromic acid do not usually cause this coloration, which is almost always due to contact of the eye with the substance itself. As a matter of fact the case of keratitis reported by Koll in 1905 was due to carrying chromium to the eye by means of a handkerchief soiled with the irritating substance; the cases reported by Bayer in 1908 occurred among workmen employed in an aniline black factory. In (1903) permanent anaesthesia of the corneal conjunctiva was observed.

As regards the ear, a few ulcers situated in the external auditory meatus have been known; more rarely still irritation of the tympanum and of the middle ear, which, however, is not at all characteristic.

Most experts admit that chromates exercise a local effect and that a general effect is scarcely likely. Others, however, speak of an action by chromates either on the respiratory or digestive passages, or on the kidney tubuli.

Ulcerations found in the mouth, tonsils, and pharynx certainly prove that particles of chromates gain access to the upper respiratory and digestive passages. But it is somewhat difficult to attribute to chromates any bronchitis, asthma, albuminuria, or nephritis observed from time to time among these workmen. The suggestion cannot be excluded that particles of chromium may be introduced by food or dirty hands into the digestive organs and there cause troubles but they are in any case very slight. Kidney lesions are very doubtful. Even though chromium was found in 4 cases out of 17 examined, at a maximum of 0.68 mg. per litre of urine, albumen was only present as a trace or was absent.

Chrome colours and lead chromate often cause lead poisoning with its well-known symptoms. Cases of ulceration or perforation of the septum among workmen who handle these colours are unknown.

Detection

(a) In the air. — Air is aspirated by means of a receptacle containing about 75 litres of water, at the rate of about one litre per minute, and passed through a filter of cotton placed at the point where it is carried into a horizontal glass tube about 25 mm. in diameter, and finally drawn through a wash bottle filled with distilled water. The amount of chromate found is estimated in the form of bi-chromate of sodium. The cotton is carefully reduced to ashes in a platinum crucible. The ashes are melted with carbonate of soda and chlorate of potassium; the product so obtained, which contains all the chromium in the form of chromate, is extracted with water, rendered acid, and reduced; then the oxide of chromium is precipitated by ammonia or weighed after suitable treatment.

(b) In the urine. — Urine to which carbonate of soda has been added is evaporated and incinerated. The residue is extracted with water, evaporated, melted with carbonate of soda and chlorate of potassium, then dissolved in water, and after that in warm dilute sulphuric acid. The ash which had been submitted to extraction at the start is rendered acid and boiled with alcohol; it is then added to the acid solution. The chromium becomes changed into sulphate of chromium. The mixture is rendered alkaline with ammonia; it is then treated by sulphuric hydrogen for an hour. The precipitate is filtered and melted with carbonate of soda and chlorate of potash; the residue is extracted with water and rendered acid. The solution is then rendered alkaline by potash lye, oxidised by hydrogen peroxide and evaporated to dryness. It is extracted by water and filtered. Chromium is detected by colorimetry or titration.

Other different methods have given results which are not as good. In particular, it is inadvisable to isolate chromium in the form of hydroxide, after transformation of the chromate into sulphate of chromium. In the same way the use of coloration of chromate of silver, with a view of detecting small quantities of chromium, is practically impossible because of the great quantities of chlorides always present.
HYGIENE

As has been said above, risk of injuries caused by droplets and dust of chromates depends not only on the industrial operation, but chiefly on the technique adopted. As a matter of fact precautionary measures and an adequate installation can so reduce the danger to a minimum that one can scarcely imagine injury to the respiratory system of the workmen being possible; while risk of cutaneous ulceration should be at a vanishing point. Ulcers may be observed, but generally the lesions are of little importance and suitable treatment rapidly cures them.

Workplaces, yards, and covered passages must be kept as far as possible free from contamination with chromates; all necessary care must be taken as soon as possible to remove chromates which soil workplaces, floors, and walls, as the result of splashing from leaky vats or of leakage from pipes, which may dry in situ. Strict cleanliness of the floors, walls, apparatus, and tools must be ensured; and also thorough cleaning whenever necessary, and at least once a quarter.

The operations of fusing the raw materials, drying the melted mass before it is cooled, and concentration and evaporation to obtain crystals of bichromates set free vapours containing particles of chromium. Hence it is essential to prevent the escape of these vapours, not only by using a closed apparatus furnished with efficient exhaust ventilation, but by installing an automatic system which reduces to a minimum, or entirely eliminates, manual labour. Melted materials, except when close to the furnace, must only be deposited in a place which is specially set apart for this purpose. If the melted material is still hot, it can be moved in any kind of receptacle; but if it is cold, trolleys or closed receptacles only must be used.

Vats for lixiviation or for evaporation, as well as other receptacles containing solutions at a higher temperature than 50° C., and acidifying vats, must be provided with an exhaust ventilating-cowl to convey the vapours outside the workplace, or better still to convey them to a chimney. This operation can be made healthy by removing fumes by aspiration or by a very efficient exhaust, when the bichromate of soda produced is not in the dry state; receptacles containing corrosive liquids must be effectually closed if the sides do not ensure the workmen efficient protection against any overflow of the solutions. The circulation of saline solutions must be carried out by a watertight system of pipes or by other mechanical means.

Every precaution must be taken to prevent any production of dust in the workplace. This is why the operations of grinding, emptying, furnace cleaning, sifting, mixing, drying, pounding, and packing must be done in hermetically-sealed apparatus with efficient exhaust ventilation, and, if possible, by automatic means. It is advisable for these operations to take place in separate workplaces. If it is not possible to prevent chrome dust from rising, or to remove it at once and completely, the workmen should be supplied by the employer with respiratory system of ventilation to protect the nose and mouth. Such respirators must be washed at least once a day and kept in good order by a responsible person. But this measure is notoriously inefficient, and it is clearly necessary to replace manual labour by mechanical processes wherever possible.

Measures must be taken to remove waste materials and waste water. Waste materials may be deposited as a temporary measure either in tanks, or ad hoc in storehouses, provided that they are protected from rain and that they do not soil the ground. The waste water must only be discharged into sewers after neutralisation.

Care must also be taken to condense nitrous vapours or to discharge them into a very high chimney.

At all works for chrome plating a good system of ventilation must be arranged above the vats. Lead material must be replaced by aluminium. The plant set up should be technically irreproachable. The workmen should be provided with means for personal cleanliness, and the personnel should be compelled to observe the prescribed regulations.

Measures for individual hygiene are very important. The workmen should be instructed as to the dangers associated with chromates and the best means of protection, either verbally or in the form of written medical examinations or by pamphlets and posters.

All candidates for work should be medically examined to make sure they have no lesion of the skin or no disease. Daily examination should be made of the hands before or after work by persons trained to detect or prevent ulceration. Medical examinations periodically and also on resuming work after absence for any cause whatever should be instituted; they are required monthly in Germany and Great Britain. Inspection of the condition of the
mucous membranes is necessary, especially those of the nose and posterior part of the mouth. In a German factory this inspection is made twice a week. The inspection must be very strict for apprentices, so that those predisposed to skin eruptions, those who show sores, the weak, and the tuberculous may be promptly eliminated. In short, an instructed and permanent labour staff informed as to the risk incurred must be ensured.

When mechanical protection is impossible or insufficient, the mouth and nose should be protected as well as the eyes and the skin.

With this in view, not only the wearing of goggles is advised, but the application to the skin of special ointments and a suitable treatment for the nasal mucous membrane is necessary. Thus, for instance, Collis and Hunt suggest the use of a substance, insoluble in water and bichromate, which is very useful for tanners. It is composed of mineral vaseline (1,360 grm.), soft paraffin (150 grm.), and cyllin (85 grm.).

Others advise the introduction into the nostrils of plugs of cotton wool moistened with a substance, insoluble in water and bichromate, which is very useful for tanners. It is composed of mineral vaseline (1,360 grm.), soft paraffin (150 grm.), and cyllin (85 grm.).

Levi, of Milwaukee, recommends the application of a pomade with a ichthyol basis, balsam of Peru, and sal ammoniac: which is very useful for tanners. It is composed of paraffin (170 grm.), ançl cyllin (85 grm.).

For the nasal mucous membrane, as well as for parts of the skin which may be exposed or be invaded by particles of chromates, a suitable treatment is necessary. Thus, for instance, Collis and Hunt suggest the use of a substance, insoluble in water and bichromate, which is very useful for tanners. It is composed of mineral vaseline (1,360 grm.), soft paraffin (150 grm.), and cyllin (85 grm.).

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Ample provision must be made for cloakrooms; for washing accommodation provided with nail-brushes and soap; for douche baths, to be taken twice a week; and for containers which should be situated so as not to be soiled by particles of chromates either from dust or fumes. (See also article "Leather and Skins").

**LEGISLATION**

The absolute exclusion of women from operations which necessitate contact with chromates is provided for in Argentina, Germany, Great Britain, Holland, Japan, and Russia; of young persons under sixteen years in Belgium and Germany; of young persons of less than eighteen years in Great Britain, Holland, Poland, and Russia; of boys of under fifteen years and women under twenty-one years in Italy; and of boys under sixteen years and women under twenty-one years in Spain.

Special legislation for alkaline chromate factories exists only in Germany (16 May 1919) and Great Britain (9 August 1913). Regulations of 21 January 1907 made in Great Britain for paints and colours and also the Belgian Royal Decree of 5 November 1910 contain provisions for dealing with colours with a basis of chromate of lead.

A British Welfare Order of 22 March 1918 provides for hygienic measures for workmen employed in tanning with bi-chromates; another of the same date provides for the protection of workmen in factories where bichromates are used for dyeing. An Order of 11 July 1922 for the chemical industry covers the manufacture of chromates, bichromates of potassium and sodium, the handling, transport, or any other work on these substances connected with their manufacture (see sections 22 et seq.).

In Russia, an Order of 1923 (no date), concerning measures of precaution to be
taken in the manufacture of chromium salts, deals with the work of adolescents and women, with the duration of work, the arrangement of the workplaces, lighting, heating, ventilation, and prophylactic measures.

For the instruction of workers leaflets have been provided by the British, German (1927), and Netherlands inspection departments. These instructions must be posted in workplaces and medical examination rooms.

Lesions caused by chromic acid and alkaline chromates are compulsorily notifiable in France, Great Britain, the Netherlands, and Russia. They are compensated as industrial accidents in the following countries: Australia (Western Australia, Queensland), Austria, Chile, Great Britain, Japan, New Zealand, Ontario, Switzerland, Venezuela and U.S.A. (Minnesota, New Jersey, New York).

These lesions are also included for compensation in other countries by a covering definition. (See article "Occupational Diseases: Compensation").

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Clerks and Office Employees

(Professional and Commercial)


As might be expected, varying degrees of risk from a health point of view attach to the varied categories of employment indicated above, including such occupations as those of commercial, railway, shipping, insurance, stockbrokers' and lawyers' clerks, Civil Service clerks, bookkeepers, stenographers, typists, travelling salesmen, porters, and messengers. Medical statistics prove that the average health of office workers is far from being satisfactory — particularly that of commercial clerks, which occupation is ranked as one of the most unhealthy in the Registrar-General's annual reports (Great Britain).

In a graded list comprising 180 occupational groups, that of clerks in general occupied the eighty-seventh position in 1911. Insurance clerks, however, rank twelfth on the list. For the period 1921-1923, in a list comprising 178 occupational groups, clerks are classed as occupying the eighty-eighth place and insurance employees (forming a single group with bank clerks) the fifty-ninth place. Insurance agents forming one group with solicitors rank ninety-seventh, whilst insurance officials occupy the third place. The reason for the low mortality among insurance officials is certainly the medical entrance examination, the encouragement and opportunity given for athletics, together with good objective conditions in general, and the same applies to Civil Service clerks, mostly recruited from a social class enjoying greater opportunity for physical development and care of health. In a list of 178 occupations given in the Registrar-General's statistics for the period 1921 to 1923, Civil Service employees and clerks occupied the seventeenth place.

The position of clerks, and especially that of commercial employees, who appear fairly low in the list, is less satisfactory from a health point of view. The reason is to be sought in various unfavourable objective conditions: struggle for existence, etc. Lawyers' clerks maintain an average position between commercial clerks and employees and Civil Service clerks.

Two sets of factors are mainly responsible for sickness and general lowered vitality found amongst these workers: first, working surroundings, and secondly, external influences indirectly dependent on work which is poorly remunerated. The first of these covers deficient air space, bad ventilation, temperature, poor lighting, and unsatisfactory sanitary conditions, as well as work in basements, at outside stalls, insecurity of employment, low salaries and high prices, excessive hours (in certain services, and at certain periods), lack of organisation, unduly early commencement of career, inferior mealtime arrangements, sedentary work, and mental and physical strain; while the second series may be said to include crowded travelling to and from business, lack of open air and physical exercise, lack of initiative and suppression of personality, inferior housing conditions, insufficient medical attention, insufficient rest and nourishment, suburban neglect of local community interests, strain of work and continuation classes after office hours, public holidays and trying conditions (travelling on public holidays), poverty, and adverse family circumstances.
An American enquiry into lost time due to sickness, covering the year ending January 1921 and relating to 1,382 office employees, revealed an annual average of 8.15 days per person, and a similar average over 8 days was arrived at by the Committee on Industrial Waste of the Federated American Engineering Societies, reporting on 42,000 male and female employees. In the first estimate the majority of employees were women, and an average of 2 days per head due to an influenza epidemic was included, but the average age of employees was only 23.7, and health was under careful supervision.

According to Emmons, during a month in the year 1920 (22 working days), the medical service of a commercial establishment was requisitioned 310 times, that is to say, benefits were accorded to 44.5 per cent. of the employees. In another commercial establishment employing 3,000 persons, medical visits amounted to 1.2 per head.

A German insurance society for clerks accorded, in the course of twelve years, benefits to 50,000 members, 16,000 of which were granted in respect of pulmonary tuberculosis.

An enquiry effected in New York relating to seventy-two firms (insurance companies, banks, wholesale manufacturers, engineering, advertising, and publication offices) showed that few firms had definite rules for payment of salary during illness, but in general payment over a "reasonable period" was reported and usually full pay for a time at least. A few firms deducted sick leave from annual leave.

Pathology

Tuberculosis is the most prevalent disease amongst law and commercial clerks. Besides pulmonary and respiratory diseases, the other effects of occupation most commonly noted amongst clerks in general are particularly neurasthenia, nervous diseases, anxiety, neurosis, eyestrain and shortsightedness, malnutrition inducing physical and mental deterioration, mental fatigue, depression, arrested growth, digestive and metabolic derangement, low vitality, mental atrophy, headaches, exhaustion, irritability, hypersensitiveness, obsessions, sleeplessness. Nervous fatigue and lowered vitality very often affect eyesight, which in turn reacts on the nerves, since the effort required for the act of concentration uses up the reserve of nerve energy and increases neurasthenia. Clerks fear nervous breakdown and ocular neurasthenia on account of dismissal, and anxiety adds to nervous fatigue. Often they cannot afford good treatment to prevent errors of refraction and only visit unskilled opticians who give incorrect advice. Apart from these general

Statistics

**British** mortality statistics (1911) for commercial clerks, by far the largest clerical group numerically — are as follows (per 1,000): phthisis and tubercular diseases, 239; diseases of the heart and circulatory system, 141; diseases of the nervous system, 128; cancer, 116; diseases of the respiratory system, 115; diseases of the digestive system, 67; and of the urinary system, 63.

For the period 1921 to 1923 these figures are: tuberculosis, 272.4; heart affections, 127.2; diseases of the circulatory system, 127.2; diseases of the nervous system, 122; cancer, 116; diseases of the respiratory system, 115; diseases of the digestive system, 67; and of the urinary system, 63.

**German** insurance statistics, 1903 to 1905, show that among 215,981 male employees there were 78,733 cases of illness, or 35.38 per cent. per annum. Of 114,894 female employees, there were 48,733 cases of illness, or 42.44 per cent. for women, being 35.8 per cent., or 3 per cent. above the general average for other occupations. The most prevalent diseases among male employees were those of the respiratory, digestive and nervous system, and among females anaemia and chlorosis (38 per cent.), followed by diseases of the respiratory, digestive and nervous system. Of the cases of sickness, 29.5 per cent. were due to accidents (chiefly porters and packers in stocktaking and shipping departments), 19 per cent. of mortality amongst store clerks was due to lung disease and between 21 and 29 per cent. among packers, while 41 per cent. of all deaths were due to tuberculosis. The mortality rates for digestive disorders (mostly gastric and intestinal catarrh, chronic constipation, gastric ulcer, haemorrhoids) were 7 to 11 per cent.

The Registrar-General's report for 1911 (Great Britain) gave the mortality rate (per thousand) for clerks as 1.78 as compared with 1.60 for all males; for insurance clerks it was 0.94; for Civil Service clerks, 1.2; railway clerks, 1.4; law clerks, 1.76; and commercial clerks as high as 2.06 or twice the rate for teachers and clergymen and nearly as great as that for dock labourers (2.9). According to the statistics for the period 1921-1923, which estimate the mortality for the total male population at 100, the various values are for clerks (excluding Civil Service and municipal clerks), 101.9; for insurance and bank clerks, 85.7; for Civil Service clerks, 73.9; for lawclerks, 117.4.

**American** mortality statistics for 1909 provide the following figures per age group and per cause of death: clerks and copyists: from twenty-five to thirty-four years of age per 100 cases from all causes: typhoid fever, 3.8; tuberculosis, 3.1; nephritis, 2.4; diphtheria, 2.1; pulmonary tuberculosis, 1.7; pneumonia, 0.7; Bright's disease, 0.2; Bright's disease, 0.8; Bright's disease, 1.1, etc.

**Pathology**

Tuberculosis is the most prevalent disease amongst law and commercial clerks. Besides pulmonary and respiratory diseases, the other effects of occupation most commonly noted amongst clerks in general are particularly neurasthenia, nervous diseases, anxiety, neurosis, eyestrain and shortsightedness, malnutrition inducing physical and mental deterioration, mental fatigue, depression, arrested growth, digestive and metabolic derangement, low vitality, mental atrophy, headaches, exhaustion, irritability, hypersensitiveness, obsessions, sleeplessness. Nervous fatigue and lowered vitality very often affect eyesight, which in turn reacts on the nerves, since the effort required for the act of concentration uses up the reserve of nerve energy and increases neurasthenia. Clerks fear nervous breakdown and ocular neurasthenia on account of dismissal, and anxiety adds to nervous fatigue. Often they cannot afford good treatment to prevent errors of refraction and only visit unskilled opticians who give incorrect advice. Apart from these general
effects, certain definite effects allied to special causes can also be noted, such as the effects of toxic products (compounds of arsenic, mercury, chromium, etc.), which have been known to cause cutaneous eruptions and irritation amongst dry goods clerks. Clerks constantly engaged in writing suffer from troubles due to sedentary life, congestion of abdominal viscerae, gastrointestinal derangements, and weakness of the legs. They may also develop writers’ cramp, which is however rare among shorthand writers but occasionally affects typists. Special occupational neuroses sometimes occur amongst stenographers and typists.

There should also be mentioned cases of poisoning which occurs at times amongst typists and roneo workers working in warm, badly ventilated rooms. In one case, volatiles being volatile products liberated from the solvents used for the inks (nitro-derivatives of benzene).

There has also been noted amongst clerks a chemical necrosis of the fingers due to pricking with aniline pencils (methyl violet, etc.) and caused by particles of aniline remaining some time within the tissue. Such cases were described for the first time in 1920 by Erdheim, of Vienna. This necrosis has, so far (1927), been reported as having occurred in about 60 cases. The lesion commences after a varying lapse of time following the pricking and is accompanied by pain and oedematous swelling without inflammation. This is followed by fistulation with serous discharge. There is no general reaction; sometimes slight discomfort, fatigue, lack of appetite, and headache. In one case only was it reported that a digestive derangement with jaundice. The normal evolution is grave, involving loss of the fingers attacked. Early surgical intervention is called for with complete removal of the particle, the more urgently since general poisoning is always to be feared and may be severe in character, even in the case of very slight and local lesions.

There should also be recalled the frequency of the alcohol habit, with its attendant effects on health, and also of venereal diseases amongst commercial travellers. Porters, messengers, etc., suffer from flat-foot and varicose veins.

**Hygiene**

Progress has without doubt already been made in regard to sanitation in mercantile establishments, but much still remains to be done, especially in provincial towns; though even in large cities bad hygienic conditions, especially in regard to lighting, ventilation, cubic space for workers, etc., are prevalent. Too often offices are situated in the basement or there is used as an office any part of a building unsuited for anything else.

Sweeping and dusting should be done by vacuum or by some other process free from dust production. Seats should also be provided especially for counting house clerks, who have to work as a rule at very high desks, and likewise for typists, etc.

Adequate artificial lighting should be provided in offices where artificial lighting has to be resorted to on account of insufficient natural lighting (basements, ground floors, first floors, rooms opening into a court, etc.). It is important to the necessity for studying better methods of heating and ventilating, better types of flooring (linoleum), etc., all of which questions are dealt with in detail in the relevant articles.

Large establishments usually provide rest rooms and medical attendance for their staffs, as well as hot meals at reasonable prices. Emmons has drawn attention to the importance of medical and dental attendance in commercial establishments.

Special attention should be paid to female workers who too often receive lower salaries than male workers, and whose living conditions are not infrequently highly unsatisfactory.

It is not possible in the compass of such a short article as the present to enter into detail regarding legal protection of clerks. A special service in the International Labour Office deals with all the problems which affect this important occupational group.

A parliamentary committee was set up in Great Britain to study conditions of work in shops. The enquiry revealed amongst other facts that often girls are engaged at too early an age and suffer greatly as a result of the undue long hours. It was even found that certain of these girls were obliged to remain in bed on Sundays in order to recover from the exhaustion and strain of work on Saturday. These conditions had for a result a large labor turnover caused by unduly hard work and constant standing.

Those who conducted the enquiry came to the conclusion that the shutting of shops at six o’clock would constitute no hardship for the shopping public and were of the opinion that certain local authorities are ready to introduce such a system in their district.

The committee expressed the opinion that the best arrangement of hours
would be to close all shops at seven o'clock for four days a week, at twelve o'clock once, and at eight o'clock on the remaining day. The eight o'clock closing should preferably occur on Friday; together with this measure a forty-eight hour week should be enforced for all clerks (House of Commons, Sitting of 13 June 1927).

In the Netherlands Chapter IV of the Royal Order of 10 August 1920, relating to the work of women and young persons, deals with conditions in offices.

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Clothing or Garment Trade


The clothing industry, comprising the manufacture of ready-made outer and under garments for men and women, had its origin less than fifty years ago, and the health conditions in the industry have consequently been very little studied. The trade owes its rise and development to the invention of the sewing machine, which completely revolutionised conditions of work in large as well as small establishments, and even in home work.

STATISTICS

It is in America that the ready-made clothing trade has been developed to its fullest extent, and it is there that one finds marked characteristics which distinguish it from the former methods of manufacture such as still exist to a great extent in European countries.

In the United States, the clothing trade is a highly organised factory industry, which may be said to have completely replaced the former system of hand-work. It has become a series of machine processes each of which is carried on under different conditions and differs entirely from the other.

The garment industry in the United States is roughly divided into three large divisions:

(a) The manufacture of men's garments.
(b) The manufacture of women's garments.
(c) The manufacture of women's underwear (petticoats, embroideries, etc.).

The considerable development attained in these different branches of the industry in the United States is proved by the fact that in 1921 there existed over 7,000 establishments engaged in the manufacture of women's clothing alone, and a somewhat less number manufacturing men's clothing. The manufacture of women's clothing represents a value of over 350 million dollars, and the number of workers engaged in these trades reaches about half a million — the two labour organisations, the Amalgamated Clothing Workers of America and the International Ladies' Garment Workers' Union, alone each claiming over 150,000 members. There are about a dozen large cities where the garment trades are concentrated, but New York is the centre of the trade, where from 60 to 75 per cent, of all the workers in the industry are employed.

The principal processes into which the garment trade is subdivided are the following: designing, cutting, sample-making, operating, basting, finishing, pressing, button-hole making, cleaning and examining. Each of these processes requires special training and skill and comprise a separate subdivision of the trade.

A special characteristic of the trade is that its workers are largely recruited from the immigrant foreign population in the cities. In New York City the proportion of workers of native origin, including coloured, does not exceed 5 per cent., the bulk of the workers being Russian Jewish, Galician Jewish, Italian and Slav immigrants.

There is little or no children's work in the trade. There is at present no home work or tenement house manufacture. In the manufacture of women's clothing, women constitute about 50 per cent. of the workers; in the men's clothing trade about 30 per cent.

The main conditions which may have an effect upon the health of the workers are the following: the sedentary character of the work in those branches of the trade where workers must sit at their work; faulty posture, stooping; improper seating; defective and insufficient lighting; lack of ventilation, and overcrowding.
There may also be some dust in handling the woolen or cotton materials and garments, and a possibility of inhalation of carbon monoxide due to leaking of gas and overheating of irons.

The report for 1926 issued by the Medical Factory Inspectorate in the Netherlands contains a reference to thirty cases of carbon monoxide poisoning amongst women workers engaged in a ready-made clothing workshop handling pressing irons heated by lighting gas.

Graham Rodgers, of New York, has conducted an investigation into the CO content of the air in workshops, and later a similar investigation was made by the United States Public Health Service, which also engaged in a study of lighting conditions.

Mention should also be made of the excessive humidity present in the workshops, especially when large quantities of steam are liberated during hot pressing.

In many countries work in the clothing industry is still done in workshops in conjunction with the aid of much home work by women who make garments, buttonholes, etc., in their own homes. This system finds still wider application in the underwear and embroidery trades (see articles "Lace Industry" and "Home Workers").

The results of an enquiry conducted in Munich by Epstein in 1904-1906 relative to health conditions in the dressmaking and sewing industry give a good idea of the situation existing in small workshops.

Out of 50 workshops visited the cubic air space in 14 cases varied between 4.2 and 10 metres per person; in 14 others between 10 and 15; in 15 cases between 15 and 20, and in 6 cases between 20 and 23. In making this estimate of the cubic space, no account was taken of the space devoted to furniture nor of bad ventilation, nor of vitiation of the air by pressing irons.

In 38 cases the workshop served also as a habitation; in 2 cases it was at the same time the kitchen for the workshop and for the family, and in 18 cases the workshop was also used for sleeping quarters.

When a member of the family fell ill, the lack of accommodation caused the workshop to be used also as a sick room. This was the case in 17 instances out of 29 families in which cases of illness were met with. The number of patients in question amounted to 34, and the different affections from which they suffered were distributed as follows: respiratory diseases, 8; digestive diseases, 2; circulatory diseases, 1; diseases of the genital system, 5 (3 affecting women); diseases of the locomotory system, 2; diseases of the nervous system, 1; infectious diseases, 12 (3 amongst children); nutritional diseases, 2; surgical cases, 1.

These affections cannot be considered as occupational diseases. Nevertheless, conditions might be considered to have been a predisposing cause, especially in the case of tuberculosis. It cannot be too often stated that faulty posture, insufficient ventilation and accumulation of dust are very important factors in favouring the development of this disease.

Another factor which experts are continuing to as of importance in connection with tuberculosis is under-nourishment due too often to the unduly low wages paid to home workers.

Furthermore, the enquiry in question brought to light the fact that in 32 of the 50 workshops visited the air was vitiated by emanations from ironing stoves in 7 cases, from coal heated irons in 20 cases, and from other types in 5 cases.

Artificial lighting also contributed to the vitiation of the atmosphere, for in 47 cases it was provided by petrol lamps (Epstein).

Under the above conditions, disease resistance — and especially resistance to infectious diseases — was bound to be greatly diminished amongst the workers concerned.

Another enquiry undertaken in 1910 by Allaria in Turin with a view to ascertaining health conditions in the garment industry has proved that amongst workers so engaged physical development was very inferior to that of normal development for young girls. Puberty was delayed by one year on an average and was accompanied by menstruation troubles. Even in the adult stage the weight and waist measurement of this category of workers was found to be inferior to the average normal weight and measurement.

Allaria found, in addition, a high degree of anaemia accompanied by insufficient pulmonary and muscular development. Having ascertained that these conditions existed already prior to entry into the trade, Allaria concluded that they could not be attributed to the occupation in question. Nevertheless, the latter, in his opinion, exerted an influence in weakening the constitution which made it at times extremely difficult to draw distinctions between constitutional defects and those caused by the work. In any case, the constitutional defects are to be attributed to social and domestic conditions of the young women engaged in the garment making industry.

In the majority of cases Allaria succeeded in ascertaining that the parents of the girls in question were town workers living in miserable conditions of privation, undermined by the effects of disease and alcoholism.

Birth rate and mortality figures estimated by Allaria for women engaged on sewing — making of underwear, etc. — and for young girls of the middle-classes have revealed an idea of the differences existing between those categories and of the effects which may be expected to follow in regard to the occupation in question.

### BIRTH RATE

| Middle-classes (scholars) | 4.7 children in each family. |
| Workers (garment making) | 5.4 |
| Peasants (making underclothing) | 6.7 |
By establishing the percentage of the families the members of which have died in childhood, the following figures are obtained:

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<th></th>
<th>Per cent.</th>
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<tr>
<td>Middle-classes (scholars)</td>
<td>22.70</td>
<td>Workers (garment making)</td>
<td>28.61</td>
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<tr>
<td>Peasants (making underclothing)</td>
<td>67.4</td>
<td>Peasants (making underclothing)</td>
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It follows that unfavourable economic and health conditions in the family are principally to blame for physiological defects found amongst the majority of these women earning their living by sewing. Further, according to Allaria's report, one-quarter of the young girls engaged on this work had no father, one-third had no mother or were orphans. Obligated in consequence to earn their living at an age when fatigue and overwork are extremely dangerous from the point of view of physical development, it is obvious that any organic weakness is bound to suffer from such unfavourable influences.

In 1911-1915 a very detailed enquiry was made by Ranelletti into the making of military clothing carried on as a home industry. He examined workers in about 200 shops in Rome where the work was almost entirely done by women (for details of this enquiry, see article "Home Workers").

In 1916 a report was published in Italy by Belloc on the embroidery industry and feminine handwork in Southern Italy. Investigations into working conditions amongst milliners conducted in Rome by Fraschetti in 1916 have shown that women workers in this industry suffer from anaemia in a percentage amounting to 90. On the other hand, there occurs among them very few cases of illness requiring hospital treatment, for amongst 9,588 patients received in hospitals from 1911-1915 there were only 25 milliners. Apart from the above no predisposition to any special disease was noted. Tuberculosis was met in 6.7 of the cases, typhoid fever in 10 per cent, and gastro-intestinal lesions in 6 per cent.

The high incidence rate for weak constitution amongst garment workers has also been explained by the fact that work of this kind demanding no considerable physical effort is chosen by preference of feeble individuals with arrested development. The poor health conditions and unsatisfactory wages only serve to aggravate the already delicate constitution of these workers. It must not be forgotten that in this industry during the "season" the working day is excessively long and causes fatigue which amounts even to exhaustion. On the other hand, spells of partial or complete unemployment between the months of July and September, and again in December and February, cause many of these workers to lose their earnings (Alexander).

In the United States this danger connected with the seasonal character of the employment has been greatly reduced by the scientific organisation of work in the garment industry. In a great part of the country, the working hours have been diminished and the control and organisation of the working conditions are now in the hands of the labour organisations concerned.

In the majority of countries the clothing trade has been made the subject of research especially in regard to home work, and it is thanks to these enquiries that health, sanitary, technical and economic conditions have been revealed. For details in regard thereto, reference should be made to the various publications relative to home work, and in particular those dealing with clothing, under wear, embroidery, etc.

Apart from the statistical data furnished by experts who have made a study of the clothing trade carried on as a domestic industry, others are available relative to health conditions of workers in the garment trade organised as a wholesale industry. There may be mentioned amongst others those of Schwab (St. Louis, 1907-1908); Schereschewsky (United States Public Health Service, 1914); Landis (Henry Phipps Institute, Philadelphia, 1914), Price (1911), etc. An investigation carried out in 1911 by Price, covering 800 workers in the cloak and suit trade, for the New York State Factory Commission showed that 16 per cent of those examined were suffering from pulmonary tuberculosis as compared with 2.4 per cent. found as the result of a simultaneous examination of 800 bakers and 1.3 per cent. found amongst 600 tobacco workers. The enquiry showed that slightly less than 13 per cent. of the workers were suffering from nervous diseases, 13 per cent. from respiratory diseases and 21 per cent. from digestive diseases.

In 1907, Schwab, of St. Louis, examined several thousand garment workers in the dispensaries of that city and his main conclusion was that about 85 per cent. of these workers suffered from what he termed "neurasthenia". According to him, this was often combined with a rapid cardiac action and general debility and was due to exhaustion from the overwork, overspeeding and intense exertion, and general nervous tension to which the workers are subjected during the rush periods, and to worry, lack of work, idleness, etc., during the prolonged slack season.

In 1914, Schereschewsky, of the United States Public Health Service, in cooperation with the Joint Board of Sanitary Control, made an intensive investigation by examination of 3,086 workers in the women's garment trade in New York City. The main conclusions of Dr. Schereschewsky were that he found among these workers an average of 4.36 per cent. defects and diseases in each individual, and that only 2 per cent. of those examined were found free from any defects or disease.
Schereschewsky was of the opinion that there were no defects and diseases peculiar to the garment trade leaving aside the effect of the sedentary character of the occupation, although it must be noted that a large part of the trade is not at all sedentary and that, notably, the cutters and the pressers — about 20 per cent. of all workers at the trade — always stand while at work.

Among the various diseases met with tuberculosis was most prevalent among garment workers with a percentage of 3.11 for males examined and 0.9 per cent. for the females — a rate, which, among the females, is nearly three times, and, among the males, nearly ten times that of the rate of this disease among the soldiers in the United States Army. The comparison, of course, is only of relative value, for the soldiers in the Army are a selected group with a much lower average age.

Apart from tuberculosis, the most common defects and diseases found in this investigation were, in order of frequency, for both sexes combined: defective vision, 69 per cent.; faulty posture, 50 per cent. (of males); chronic nose and throat affections, 26.2 per cent.; defective teeth, 26 per cent.; pyorrhoea alveolaris, 20 per cent.; weak and flat feet, 26 per cent.; chronic constipation, 23.7 per cent.; dysmenorrhoea, 20.2 per cent. (females); hypertrophied tonsils, 15.3 per cent.; defective hearing, 10 per cent.; nervous affections, 7.75 per cent.

Chronic catarrhal affections of the nose and throat were very prevalent. These were found to be the cause of considerable discomfort to the workers. The garment trades in themselves, however, did not seem directly responsible for the existence of these conditions as, in many instances, they had apparently existed from childhood. The great prevalence of these diseases may be partly accounted for by the fact that the great majority of garment workers have been city dwellers from birth, and, presumably, always exposed to the crowded and congested conditions said to favour the genesis of chronic nasopharyngeal affections.

Nervous affections, particularly neurasthenia, were very common, especially among males. Piece-workers were found mainly to be affected. The element in the garment trades thought to be particularly active as an aetiological factor was the characteristic fluctuation in seasonal activity of the industry.

Schereschewsky concluded that, on the whole, a large part of the defects and diseases of garment workers arose from ignorance or neglect of personal hygiene.

The investigation of Landis, the report of which was published by the Henry Phipps Institute in 1915, was based upon a thorough examination of 1,000 workers, of whom 743 were studied intensively. A considerable number of workers are found to suffer from tuberculosis: 51 out of 402 males and 21 out of 241 females were found to be tuberculous. This is evidently too high a rate, and is due to the fact that not only active processes in the lungs, but many with chronic fibrosis were termed tuberculous.

Landis also found an excessive number of so-called "red eyes"; or conjunctivitis, and other affections, especially among the pressers.

Between 1911 and 1924 there were conducted at the Union Health Centre of New York City over 60,000 physical examinations of female workers, some of the results of which have been previously published. A general résumé of the findings may be given as follows.

The general health of the workers in the women's garment trade is not worse than that of the workers in kindred trades, and there are very few special occupational defects among these workers.

A large number of the workers — 25 per cent. — suffer from one or more digestive diseases, many of these of a nervous type. Gastritis, gastralgia, gastric and duodenal ulcers, appendicitis, and colitis are among the most frequent of the gastric ailments.

About 25 per cent. of the workers are suffering from general nervous defects — neurasthenia, neuritis, etc. — very few from serious neurotic and cerebral spinal diseases.

A large group, about 15 per cent., are suffering from respiratory diseases — chronic bronchitis, asthma, emphysema and fibroid phthisis.

About 10 per cent. of the workers suffer from chronic cardiac and circulatory diseases, hyper- and hypotension, with a few cases of aortic dilatation, aneurysms, and auricular flutter and fibrillation. It is highly probable that these cardiac troubles are connected with the faulty posture adopted by the workers as well as with deformation of the spinal column.

According to statistics assembled by the Pressers' Local of the Garment Workers' Union, amongst 5,000 members at the end of 1922, there had occurred during eight years 2,246 cases of sickness, with a total number of 10,301 weeks of sickness, an average of four and three-fifth weeks per case. The number of cases of sickness per annum ranged from 4.9 per cent. to 6.9 per cent. of the total membership.

As to duration of sickness, the 2,246 cases, 19 per cent. lasted ten weeks, 30 per cent. from four to nine weeks, and the remainder less than four weeks.

As regards pulmonary tuberculosis, while the percentage of fibroid phthisis is so relatively high as to range from 5 per cent. to 8 per cent., active pulmonary tuberculosis, with positive sputum, is found only in less than 1 per cent. of the workers, a much smaller percentage than that found in the previous examinations mentioned.

Among the pressers, with 5,000 members, there were within the last ten years 129 cases of active pulmonary tuberculosis. However, this figure comprises only those to whom a sick benefit was paid and does not represent all the active pulmonary tuberculosis cases among the membership.

According to the data furnished by the Association of Sickness Insurance Funds
of Vienna and Lower Austria for the year 1924 (Adler-Herzmark), the number of insured persons belonging to the clothing trade and fur trade amounted to 14,004 — 9,391 being women. The number of diseases reached 7,419 and deaths 79. There were included therein 1,983 cases of tuberculosis with 32 deaths. The number of days of sickness amounted to 81,887. The number of patients amongst the men reached 1,640 (34.87 per cent.) and amongst the women 5,799 (61.53 per cent.). Of the total number of insured male workers 7.84 per cent. suffered from tuberculosis, whilst for the female workers this percentage was 17.18. The death rate was considerably higher amongst the men than amongst the women. Amongst the former it reached 43 deaths, 13 of which were due to tuberculosis, whilst for the female workers this figure was 36, 19 being from tuberculosis.

The various diseases reported are distributed as follows:

<table>
<thead>
<tr>
<th>Disease Type</th>
<th>Percentage Men</th>
<th>Percentage Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anaemia</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>Respiratory diseases</td>
<td>12.4</td>
<td>19.8</td>
</tr>
<tr>
<td>Of which Tuberculosis accounted for</td>
<td>7.84</td>
<td>17.18</td>
</tr>
<tr>
<td>Tuberculosis of the other organs</td>
<td>0.73</td>
<td>0.90</td>
</tr>
<tr>
<td>Digestive diseases</td>
<td>4.17</td>
<td>9.53</td>
</tr>
<tr>
<td>Circulatory diseases</td>
<td>1.17</td>
<td>1.53</td>
</tr>
<tr>
<td>Nervous diseases</td>
<td>1.18</td>
<td>9.48</td>
</tr>
<tr>
<td>Congenital diseases</td>
<td>0.65</td>
<td>2.55</td>
</tr>
<tr>
<td>Of which Venerial diseases</td>
<td>0.50</td>
<td>1.90</td>
</tr>
<tr>
<td>accounted for</td>
<td>4.5</td>
<td>6.57</td>
</tr>
<tr>
<td>Sense organs</td>
<td>1.91</td>
<td>0.83</td>
</tr>
<tr>
<td>Infectious diseases</td>
<td>4.86</td>
<td>7.50</td>
</tr>
<tr>
<td>Of which Influenza accounted for</td>
<td>4.5</td>
<td>6.57</td>
</tr>
<tr>
<td>Diseases of the locomotory system</td>
<td>0.7</td>
<td>3.31</td>
</tr>
<tr>
<td>Skin diseases</td>
<td>2.3</td>
<td>3.05</td>
</tr>
<tr>
<td>Malignant tumours</td>
<td>0.3</td>
<td>0.0</td>
</tr>
<tr>
<td>Surgical defects</td>
<td>0.91</td>
<td>6.48</td>
</tr>
<tr>
<td>Miscarriage</td>
<td>—</td>
<td>0.94</td>
</tr>
<tr>
<td>Various</td>
<td>—</td>
<td>0.60</td>
</tr>
</tbody>
</table>

**Pathology**

Anaemia, chlorosis weakness, defective physical development, pre-tuberculosis affections and genital hypoplasia are said to be fairly frequent amongst needlewomen (Hirsch).

The statistics of the Leipzig Sickness Fund provide the following figures for women workers in the ready-made garment industry:

<table>
<thead>
<tr>
<th>Category</th>
<th>Per 1,000 living</th>
<th>Percentage of deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garment workers (clothing trade: underclothing)</td>
<td>21.7 30.2</td>
<td>0.56</td>
</tr>
<tr>
<td>Other women workers in the ready made garment industry</td>
<td>22.3 33.9</td>
<td>0.81 1.69</td>
</tr>
<tr>
<td>All female members of the Fund</td>
<td>21.0 21.1</td>
<td>0.57 1.18</td>
</tr>
</tbody>
</table>

Many experts draw attention to the importance of chlorosis, which formerly showed a high incidence especially amongst young workers in the clothing industry. Under-nourishment, the sedentary life and days passed in a vitiated atmosphere, etc., favoured the outbreak of this disease. The use of electricity to replace gas and coal doubtless explains the present decrease in cases of this nature (Agasse-Lafont).

**Nervous troubles**, which are fairly frequently met with, particularly troubles of a functional order, are, according to specialists on the subject, not due to the occupation, but are the expression of diathesis in individuals with physical defects or weak constitution, from which class the workers in this trade are as a rule recruited.

There has, however, been noted trembling of the hands and eyelids (Katznelson) and a form of cramp peculiar to workers employed in sewing, which affects dressmakers, tailors, etc., and has its site in the thumb and forefinger of the right hand. Another site was observed in the case of a dressmaker who, when she commenced sewing, was seized with cramp in the pronators of the hand. When she attempted knitting it was the extensors and the adductors of the arm which were affected (Montesano).

Cramp may likewise be situated in the muscles of the arm or shoulder, especially in the case of tailors working with stiff materials and using large scissors. Finally, a form of cramp causing internal rotation of the arm by contraction of the infrascapular muscle has been described in the case of a dressmaker by Duchenne. With regard to the lower limbs, there has been described a functional dyskinesia as the result of working a foot machine. Moreover, cramp of the flexor muscle of the foot has been noted by Remak. A form of paralysis known as "scissors" has been met with amongst workers frequently handling scissors, the pressure of which against the thenar eminence may in the long run cause atrophy of the muscles and permanent paralysis. The latter represents the case of an organic occupational lesion and can no longer be considered as neurosis attendant on the occupation.

Particular importance has been accorded to diseases of the female genital system, and there have been attributed to constant standing and to working at the sewing machine dysmenorrhoea, endometritis, vaginitis, and retro and anti version of the uterus, etc. The percentage of men-
stration troubles amongst sewing machinists has been quoted as 15.7 per cent. whilst for needle workers the figure did not exceed 3.5 per cent. (Lehmann). Similarly, the incidence of miscarriages amongst machinists has been found to be higher than ironers (Margoniner). Gutzmann (1895), in resuming the study of the influence of work at the sewing machine (see also later article on the genital organs of women), showed that amongst 356 female garment makers receiving hospital treatment at the Charity Polyclinic in Berlin, inflammation of the appendices affected 18.8 per cent., pelvic peritonitis 12 per cent., diseases of the uterus 21 per cent., retroversion 23.3 per cent., and miscarriages 13.2 per cent., pelvic peritonitis 12 per cent., diseases amongst 403 women garment workers (Sofoterow).

Cases of extra-genital syphilis infection noted amongst garment workers have been attributed to the bad habit that these women have of keeping thread and pins in their mouths (Hirsche). It is further likely that other infections also are principally attributable to the same bad habit (tuberculosis, sore throats, etc.). This is the more likely to occur since use is made of old pins picked up from the dust of the work-room floor and not sterilised (Agasse-Lafont).

There have also been reported cases of poisoning due to manipulation of materials, fringes, silk threads, etc., impregnated with lead or dyed with lead or arsenic colours. Finally, poisoning by carbon dioxide given off by combustibles (coal gas used for heating the pressing irons) has been reported (Sokolow).

In certain branches of the ready-made industry (millinery) there are used varnishes with benzene or carbon tetrachloride basis, etc. The Health Office of Ohio found, for instance, in analysing products of this kind a benzene content of 92 per cent. In general, workers engaged on sewing, and particularly in making underclothing, frequently present troubles of refraction and accommodation, phosphene, etc., due to close work on light or white materials (see article "Textile Industry" for ocular troubles amongst fine drawers of material). Troubles of accommodation are manifested in hypertonicity of the ciliary muscle. Asthenopia has been noted amongst long-sighted women workers who refuse to wear glasses, often for reasons of vanity, etc. In these cases the victims complain of a sensation of burning of the eyes, of headaches located on the forehead, of somnolence, fatigue, photopsia, etc.

Very often the individuals in question are of a nervous type of constitution, amongst whom the conditions of work set up ocular troubles with the clinical symptoms observed. This type of patient presents defects of refraction, of accommodation and the muscular insufficiency which cannot be detected. However, minute examination shows up in certain cases shrinking of the visual field and especially a characteristic deviation of this field designated under the term "hysterical copiopia".

Ocular troubles are particularly frequent amongst workers engaged in their homes with insufficient or unsuitable lighting, as, for instance, in village establishments. Sokolow noted that weavers and home workers engaged in sewing living in rural habitations are victims of myopia, of conjunctival catarrh and other troubles of the same order. This same author has remarked on the frequent incidence of myopia amongst the children of these workers. The habit of giving these children needles to thread would explain to some extent why they suffer from myopia to a degree 5 per cent. in advance of the figures for children in general, and why the incidence of eye diseases amongst them exceeded the general average of 2.5 per cent. (Bouschbek).

Amongst young dressmakers the incidence of myopia has been estimated at 10 per cent. higher than that for young girls in technical schools. For embroidery workers the frequency is said to be still greater, i.e. 42.9 per cent. These facts, however, do not justify definite conclusions being drawn as the observations were limited to an unduly small number of workers (Lawrentieff). Finally, nystagmus has been observed amongst English garment workers (Collis).

The manipulation of materials dyed with different colouring matters may give rise to cutaneous irritation. There has been described, for instance, cases of eczema affecting 16 tailors, 4 shirtmakers, 10 apprentices, one tailor's foreman and 4 hotpressers (Knowles). A case of erysipeloid has been described as affecting a dressmaker (Reisch). The unduly early occupation of children, especially of girls, and women on garment making explains, according to certain authors, frequent troubles affecting physical development, menstruation, etc., noted amongst the
women workers. Repetition of the same movements and faulty and uncomfortable posture are to be held responsible for a great many of the deformities and occupational stigmata met with. Earlier authors (Ramazzini, Stoll, Schann) have left a sad picture of the tailors of their time, and at the present time in the making of men’s suits to order the tailor carries out the work much in the same way that his predecessor did. Being obliged to sew by hand a part of the suit at least, the worker is seated at a table with his legs crossed, his body bent forward in a position which exposes him to digestive and circulatory troubles, especially of the lower limbs, and to congestion of the liver, etc.

From the above, it is seen that, especially in regions where modern methods of work have not so far been introduced, the actual state of conditions at present resembles fairly closely the description provided by former writers (Layet).

Amongst occupational stigmata there should be mentioned pricking of the fingers and small losses of substance at the level of the right index finger. On the other hand, an inward deviation of the first and middle finger accompanied by a slight external deviation of the ring finger is characteristic of the hand of a tailor or dressmaker. Further, the small phalanges of the index and middle finger are clearly attenuated and assume the form of a spindle.

As regards dental troubles, it has been remarked that the incisors, especially the average upper and lower incisor, present a characteristic alteration due to a mechanical cause, namely, the bad habit of cutting the thread with the teeth and of holding pins between these. This habit in the long run causes them to be worn into a groove. Dental caries is not very frequent as will be seen from a comparison made between dressmakers and the average for all occupations (Rose):

<table>
<thead>
<tr>
<th>Number of teeth examined</th>
<th>Number of unsound teeth</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dressmakers</td>
<td>413</td>
<td>12,289</td>
</tr>
<tr>
<td>Average figure for all occupations</td>
<td>11,874</td>
<td>253,377</td>
</tr>
</tbody>
</table>

On an average each women worker of this category had 7.1 unsound teeth (average for all occupations, 7.9) and 5.1 teeth free from caries (average for all occupations, 5.9).

It would certainly be advisable to analyse here in detail the digestive disorders caused by lack of time for meals, meals at irregular hours, sedentary work immediately after eating, and under-nourishment of workers who receive payment in kind or have meals supplied on the premises, etc. A whole series of recurring troubles result from the above conditions, favouring the outbreak of chronic gastric ulcers of the stomach and duodenum, of cholecystitis and adhesions, of appendicitis, constipation, piles, etc. The sedentary position or constant standing for a long period without moving causes varicose veins with all their attendant consequences.

Characteristic callosities have been noticed on the phalanx of the left index finger. They are caused by using the needle. Others on the palm of the right hand, as well as on the fingers of this hand palm side, are due to pressure from the pressing iron.

Burns from the pressing iron are often met with on the fingers of the right hand. The fumes given off in course of ironing materials, especially men’s jackets, may cause burns which have their site mostly on the nail of the forefinger and middle finger of the left hand and on the phalanges of the middle and index finger of the right hand (back and inside of the hand). Finally, the use of large scissors may cause backward displacement of the thumb (Layet).

In the United States an examination of young women garment makers (1913) engaged on home work showed a very high incidence of cases of deformation of the bones, amongst which scoliosis reached the high figure of 66 per cent. These deformations have been attributed to latent rickets caused to develop by the occupation and continuous work at the sewing machine. They are accompanied by pains in the
gastric region, headaches, nervous troubles, etc. (Blanchart). Attention has been drawn also to deformation of the spine by Katznelson among scholars in a technical school (manufacture of ready made garments) at Moscow.

As early as 1860 (Gardner) came to the conclusion that work at a sewing machine had a very harmful influence on the health. He also held, however, that dressmakers' work was becoming less exhausting, and that the movements of the feet required might even exert a favourable influence on the health. He thought that the use of the sewing machine within reasonable limits could not, on the whole, involve more serious consequences for the health than ordinary needlework executed by hand.

His opinion has not been shared by Vernois, Down and others who have drawn attention to the case of home workers obliged to use a pedal sewing machine during a long working day and often during the night. It is held that the special attitude required, more especially in the case of stout persons, the vibration, etc., create special seats of injury and cases of nervous excitement and irritation of the genital organs.

Recent observations relating to sewing machine work have led to the following conclusions. In the case of the hand machine, the worker is obliged to guide her work with the left hand while the right is engaged in turning the handle. The pedalling machine, on the other hand, allows the worker both hands free, thus greatly increasing her efficiency and making it possible to arrive at a speed of 600 to 700 stitches per minute as compared with 300 for the hand machine. By means of improvements in the shuttle, speed has been further increased from 800 to 1,000 stitches a minute, while the application of electricity to the machine has still further increased the figure to 3,500 stitches per minute (Foster). While the machine with motive power constitutes a certain relief for the worker and diminishes her muscular fatigue, on the other hand it demands great effort of concentration and considerable visual effort. The speed of the electric sewing machine is on an average from 1,500 to 2,000 a minute during several hours. It entails an increase of about 50 per cent. in speed, but it must be considered whether in the long run the conditions do not react on the workers' health, causing physical and psychic injury, more especially in the case of weak and predisposed individuals. It is interesting to note finally that research undertaken in regard to ocular fatigue amongst machine workers in England have demonstrated that the wearing of glasses for correcting the sight had the effect of lightening the work for those employed and of increasing production. The glasses in question were intended to eliminate the effort of accommodation, and the results obtained have led to the conclusion that an attempt by correction of convergence would be followed by still more favourable results. No discomfort was felt by the workers and no interference with normal vision was remarked at laying aside the glasses at the end of the working day (Weston and Adams).

**HYGIENE**

As has already been seen, hygienic conditions vary enormously in accordance with the technical organisation, that is to say, as to whether the work involved is home work or in workshops which are or are not under the control of the factory inspectorate, or in large factories following modern technical methods.

The ready made clothing industry was originally run on the "sweating system". During its primary development the work was almost entirely done in the worker's home rather than in specially constructed workshops. In many countries the work, whether it be done in the town or in the country, is still home work and often as a means of obtaining supplementary earnings for the woman worker who engages therein, either alone or with someone to assist her. Hygienic conditions of the woman worker in this case, whether she works for customers or for an employer, are strictly connected with her housing conditions and, it might even be said, with the economic status of the woman or her family. For reference to such conditions see article "Home Workers".

The sweatshop conditions were due originally in America to the immigrant source of labour, to the crowded section in which the garment industry had its beginning, the small capital needed for establishing new workshops and the exploitation of the industry by rising small capitalists and contractors who were compelled by competition to cheapen the products and reduce expenses to a minimum.

From the first, there were many complaints by the Labour people and their sympathisers against the insanitary conditions which were charac-
teristic of the garment industry, and a number of State and Federal investigations took cognisance of the so-called sweatshop work and from time to time proposed legislative enactments to improve these conditions.

However, few if any scientific investigations were made into the sanitary conditions of the trade until 1911, when the formation of the Joint Board of Sanitary Control in New York City gave the first impetus to the sanitary survey of the workshops and the elimination of the worst sanitary conditions in the trade.

Since 1911, State and municipal efforts, as well as the endeavours of the employers and workers in the trades, have resulted in much improvement in the sanitary conditions of the workshops, and at present the stigma of "sweatshop" can hardly be applied to them, especially those in the larger cities.

There were very few investigations of the sanitary conditions of the shops and practically no investigations at all of the health of the workers in the garment industry prior to 1910 and 1911. Even later, whatever investigations were made were limited to the women's garment trade in the cities of New York and Philadelphia.

Sanitary investigations of the workshops were made in a cursory manner by various State Labour Commissions and Factory Inspection Departments, but the first scientific survey of the women's garment trade was made in 1911 by the Joint Board of Sanitary Control, which then investigated all the shops in the cloak and suit industry, and later those in the dress and waist industry. Sanitary investigations have been continued since then by the semi-annual and other special investigations carried on by the Joint Board of Sanitary Control.

As a result of the various investigations made by this Board, it has evolved a set of standards for the industry, which it has subsequently been enforcing. By 1924, these standards had been so effectively applied as to leave only 374 shops (about 10 per cent.) which the Board classes as "C", meaning thereby that they had serious defects in fire protection and sanitation.

A sanitary inspection of the shops in the men's clothing trade in the City was effected in 1919 and conditions were found to be much worse than those in the women's clothing trade (G. M. Price).

The choice of a suitable seating accommodation is of capital importance for workers in the industry in question, especially for workers manipulating a sewing machine. The seat should be wide and not deep, slightly concave, and the front edge should be rounded. The feet should rest comfortably on the ground or on a support fixed to the floor or to the table. The distance between the table and the seat should permit of sufficient space to allow of the free movement of the knees. There should be no bar or other obstacle to hamper the position of the feet. The chair should have a back for supporting the lower part of the workers' back, which should not be too high in order not to interfere with the arm movement. Well constructed chairs fail to fulfil their purpose if they are not adapted to the nature of the work and to the place in which it is carried on (Industrial Committee of the State of New York).

In other countries, especially in those where modern industrial development has not been introduced, garment-making workshops have only too often very unsatisfactory hygienic conditions. The cubic air space is below the required minimum, ventilation defective, the atmosphere vitiated, natural lighting absent and artificial lighting inadequate (Magrini).

In millinery workrooms hygienic conditions are no better. Thus, for example, besides the lack of space, there were reported in Rome in 6 per cent. of the cases investigated undue humidity and complete lack of windows. In sale-rooms in the same town the door was the only opening in 63 per cent. of the cases visited, and it served at the same time as the only means of ventilation and lighting (Fraschetti).

THE "MATERIAL" FACTOR

In this industry, more especially perhaps than in others, the factor "material" plays a very important role in the lighting problem. A question which is deserving of all attention is that of the diffusion coefficient of the different pieces of work, a coefficient which is not the same for different lighting sources. When the coefficient is low, increased lighting power is necessary.

This diffusion power varies considerably. In an American study of 1915 into hygienic conditions of illumination in the women's garment industry, the percentage albedo of the various materials is reckoned as follows: black velvet, 0.37; dark navy blue serge, 1.7; black serge, 1.9; light navy serge, 2.2; green or dark green serge or cotton, 2.3; black cotton, 2.9; black silk or mercerised cotton, 4.5; light green cotton or serge, 5.4; light natural wool, 10.9; tango wool or cotton,
workers to the cubic space, and lighting of these are subject to Government in-
der the work less trying. 

minimurq of measures calculated to ren-

Light clothing should, however, be worn,
white cloth, 65.9.

The factory inspectorato for such reasons as
latter times, however, in certain countries these

The sewing machines, either pedal or motor.

Other supplementary measures are
required to complete these, in regard, for
instance, to adequate seating accommoda-
tion for workers engaged in manipulating
sewing machines, either pedal or motor.

The daily working hours, the age of
admission of young girls to the work,
etc., are all matters for regulation with-
out, however, entering on the subject of
economic conditions, which are of such
capital importance in the clothing in-
dustry.

In the absence of legal provisions, it is
the municipal authority which is en-
trusted with inspecting housing conditions
in general, and in particular those dwell-
ing houses used as workshops. Some-
times, however, in certain countries these
latter are not subject to visits by the
factory inspectorate for such reasons as
the following — restricted number of
persons employed, work effected exclu-
sively by one family, absence of motive
power, etc.

Special legislative provisions have been
issued in regard to protection of eyesight
by laying down conditions with regard to
artificial lighting of workshops in general, and in particular those in which
fine and extremely fine work is effected.
Thus, for example, the American * standard code and the various industrial
lighting codes for the States of North
America, as well as the English regula-
tions, etc., demand fairly high lighting
values for any industry requiring a de-
tailed visual effort. The British Depart-
mental Committee on Lighting has re-
quired for the following work a minimum
lighting standard of 30 lux: sewing by
hand or by machine light coloured mate-
rials (including hemming, pleating, brand-
ing, mending, pressing and ironing by
hand, cutting by hand or by machine
with the exception of cutting with a band
knife), and for the same operations on
dark coloured cloth (making buttonholes
by hand, sewing fur by hand, darning,
cutting with a band knife) a minimum
standard of 50 lux.

Existing legislation is chiefly concerned
with domestic work: in Finland an Act
dated 17 May 1927 relates to safety in the
clothing industry; in the Netherlands an
Act enteries obligatory notification of
cases of cramp occurring amongst work-
ers in the clothing trade.

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The composition of tar varies according to the nature of the coal distilled, the apparatus used, and the temperature at which distillation is carried out. Whatever the case may be, the principal constituents of coal tar are:

1. Hydrocarbons: benzene and its homologues, naphthalene, anthracene, etc.
2. Phenols, cresols, naphthols.
3. Sulphur compounds: sulphuretted hydrogen gas, carbon bisulphide, ammonium sulphide, etc.
4. Nitrogen compounds: ammonia-aniline, pyridene, acridine, cyanogen compounds, etc.
5. Water, finally, which contains in solution some ammonia.

Tar is used after having been more or less purified, or in the crude state, with further treatment, in the manufacture of lacquers, especially anti-rust paints for metal parts (ships), briquettes, patent fuel, tarred cloth, paper and felt, string and brattice cloth of rubber, lamp black (by the incomplete combustion of pitch and tarry oils) for coating the internal walls of Bessemer converters, for the manufacture of electrodes, for making roads, in rope making, in the rubber industry, in cork work, for impregnating wood, in the manufacture of books, etc.

**INDUSTRIAL PROCESSES**

The treatment of coal tar so as to obtain the different constituents is carried out in tar distilleries.

The tar arrives in barrels, tank wagons, and tank steamers and is generally unloaded by pumping. It is kept in large reservoirs in which the ammoniacal waters separate out, gradually collecting on the top of the tar. This operation is often assisted, especially in winter, by the application of slight heat provided normally in the form of steam coils arranged in the walls of the reservoirs.

The ammoniacal waters, containing ammonium sulphide and cyanide, have an unpleasant smell. They are withdrawn, collected in close receptacles and sent to ammonia factories.

The tar, thus freed from the greatest part of its ammoniacal waters, is then distilled in vertical stills or in large tubular boilers. The boiling vessels made of masonry are generally provided with a hearth in front; they are heated by coal, coke, gas or oil.

In modern technique, the tar, before entering the still proper, is made to traverse slowly a small still in which it is warmed to a temperature of about 140° C. in order to drive off such water as remains. This process gives off ammoniacal and sulphurous gases, then before or at the same time as the water vapour issuing from the normal wall: carbon bisulphide, benzene, toluene, etc. The vapours escaping are condensed in a refrigerating plant yielding an aqueous liquid on which float the oils. The water is separated from these and reunites with the ammoniacal waters.

The heating of the still and pre-distillation is effected by the vapours given off from the principal still which pass into large pipes where they are condensed. The pre-distillation apparatus thus acts as a cooler in relation to them.

In the course of the distillation of the crude tar or of the tar freed, so to speak, of its water and a part of the light oils, the other constituents of the tar are separated on fixed lines.
In general the fractionation is effected according to the specific gravity or follows the boiling points. In the latter case, the light oils are separated at a point below 180° C., medium oils or phenols between 180° and 250° C., naphthalenes or heavy oils between 250° and 300°, and anthracene and such like between 300° and 350° C. After the removal of the oils and naphthalene generally, live steam is introduced to dilute the tar, to accelerate its vaporisation and prevent its calcination.

Cooling and condensation of the gases distilled are carried out in refrigerators utilising water or crude tar as the means of cooling. This process must be very carefully regulated, because condensation of compounds coming off at the highest boiling points must not be cooled too much for fear of depositing the naphthalene and choking the cooler. It follows that the cooling apparatus is made as far as possible of such materials as will allow of easy opening and cleaning. Further, as blocking of the stillage pipes may take place sometimes, the predistillation apparatus must be provided with valves or safety arrangements to prevent the production of too high a pressure.

When the tar does not undergo predistillation the stills ought not to be too full, because the tar froths a great deal in consequence of the evolution of the gaseous constituents and of the steam, so that it can easily overflow.

After the removal of the anthracene oils, there remains in the still a hot, thick liquid residue, the coal tar pitch. While still hot, this residue is directed along a special pipe into covered-in receptacles to prevent a too strong evolution of the yellow fumes which are generally present. The pitch remains in the receptacles until it is cooled to about 100-150° C., a temperature at which it is still liquid, then it is cooled in pits where it solidifies.

Distillation is actually carried out, often entirely, or if not, then partly, under a negative pressure, and at the same time a little steam is injected into the tar. The different products obtained in the course of distillation are sometimes sold or used directly without any further manipulation. The light oils are nevertheless distilled at least once more and fractionated into different substances. Prior to that, in order to remove the phenols, they are treated with soda lye in iron cylinders contracted at the bottom. The passage of the mixture is ensured by means of mechanical agitators or a current of air. The oils, separated from the soda lye, are washed, treated — stirring going on all the while — with dilute sulphuric acid which removes the fumes of pyridene. They are then treated with strong sulphuric acid of 66° B. strength, which dissolves and separates the resinous products mixed with them. The oils thus purified are distilled in column apparatus and fractionated generally into 90 per cent., 50 per cent. benzol, solvent benzol and heavy benzol.

From the soda solution the phenols are removed by neutralisation with sulphuric acid or carbon dioxide. This process is accompanied sometimes by the development of poisonous gases, especially of sulphuretted hydrogen gas and cyanogen compounds, so much so that this acidification should be carried out in closed receptacles provided with good exhaust ventilation. In 1910, for example, a fatal case of poisoning from sulphuretted hydrogen gas occurred at this process in Germany.

The latter processes for the separation of the stillage are not generally carried out in tar distilleries. The medium oils yield naphthalene on cooling and resting, which precipitates in the form of crystals. On filtration the phenols separate out and then it is subjected to pressure first in the cold, then heated, and redistilled. During this process watch must be carefully kept lest the coils of the stillage and cooling apparatus become blocked, which, if it occurred, might easily lead to an explosion in the apparatus. They must, therefore, be provided with safety arrangements allowing vent to excess of pressure in case such a blockage should occur.

The phenols separated from the naphthalene are usually employed for the impregnation of wood. Sometimes the phenols are also withdrawn by separating them from the cresols. The procedure is the same as in the case of the light oils; except that only a small quantity of the soda lye is used, insufficient for bringing into solution all the phenols. It is almost exclusively pure phenol (C₆H₅OH) which passes into solution, because it is notably more acidic than its homologues. A certain fractionisation is thus obtained.

The heavy oils are not generally treated further; they are mostly used as they are for impregnating wood and railway sleepers, as a fuel in oil heating installations, and as fuel in Diesel internal-combustion engines as well as in blast furnaces. They are also used as puttying materials.

The anthracene oils yield, on cooling, in crystalline form, anthracene mixed with other products. Anthracene is then separated from the oils by filtration in vacuo, and the product obtained
is then subjected to hydraulic pressure. The resulting caked mass, which contains about 40 per cent. of anthracene, is then ground, yielding commercial anthracene. The oils separated out are utilised as a fuel or for lubrication.

**Sources of Danger**

The processes described are those which have been generally used up to the present time. The stills must be filled every time, emptied, cleaned and freshly filled, which is uneconomical. The stills and the masonry undergo deterioration by successive heating and cooling. They become leaky. The tar which escapes may commence to take fire and in certain cases gives rise to serious fires. The stills which have been generally used up to the present time.

The stills contains about 40 per cent. of anthracene, which is uneconomical. The stills and the masonry undergo deterioration by successive heating and cooling. They become leaky. The tar which escapes may commence to take fire and in certain cases gives rise to serious fires. The stills which have been generally used up to the present time.

In 1905, 5 fatal cases were reported from a factory which ten years before also had 5 fatalities among workmen engaged in repairing a still.

In 1897, 3 fatal cases occurred to workmen engaged in scraping a still who had worked up to the breakfast interval without having felt anything amiss. On resuming work one of the men became unconscious, and the two others also lost consciousness in the effort to save their mate. The still in question had a pipe in common with another still. Through this the toxic gases coming from one still had reached the other in process of being cleaned during the breakfast interval. Such an accident shows how absolutely necessary it is to shut off all possible connections before going inside.

In 1920, three workmen in a tar distillery became unconscious on going into a place where pitch was stored and filled with toxic gases, but they were saved by the administration of oxygen.

The working of tar distilleries requires that workpeople should enter oil cisterns, stills and other receptacles with a view to cleaning them. This work is dangerous enough because of the injurious emanations from the tarry oils which are always present in the receptacles, as well as in the condensing chambers (carbo-sulphurous fumes, fumes of hydro sulphuric acid and ammonia, etc.).

Raschig has put up at Ludwigshafen a continuous distillation process allowing of minute fractionating of the different compounds. The distillation is carried out in great part under a negative pressure; the heating of each receptacle and still is done by ordinary steam, superheated steam or water heated to 300° C. The boilers for the steam or for superheating the water are contained in special buildings away from those in which the processes of distillation are carried on. Automatic pumps conduct the tar slowly but uninterruptedly into the stills. The operations being continuous are consequently very economical. The workpeople hardly come into contact with the compounds and are engaged mainly in keeping a watch; which, from the point of view of hygiene, marks the process as one of considerable advance.

Tar oils and their emanations as well as sulphur dioxide are inflammable and can form, when mixed with air, explosive mixtures (Leymann).

**Statistics**

A survey of the number of insured works in Germany, of the accidents giving the right to compensation, and the number of fatalities is given in the table on pages 464-465. The accidents include also the acute poisonings, of which the number is relatively small. Tar distillation is shown in col. 7. Comparison with the other branches of the chemical industry shows that in this industry the danger of accident is particularly high.

In Germany cases of tar eczema are reported, especially among the pitch breakers, but not a single case of tar cancer. The report of the Factory Inspectorate for the year 1902 describes obstinate skin lesions, sometimes severe, among workpeople using anthracene in Upper Silesia. Among 30 persons employed for a period of ten years, 22 suffered from eruptions on the hands, arms, feet, knees, neck, chest and back. In three cases operation had to be practised on the scrotum of three workmen after six to eight years' employment. The measures subsequently taken by the firm seem to have been attended with good results as no further cases have been reported.

Examination of 2,500 workmen employed in 165 patent fuel works in Prussia brought to light 10 definite cases of skin cancer (many of them multiple) situated on the face and most frequently on the scrotum. The majority of the cases were cured by surgical intervention. Some cases have been found among those employed on coke ovens.

In 1918, 67 industrial premises were visited in the neighbourhood of Essen with the object of determining the lesions produced by the substances handled. Among them were 27 patent fuel works, tar distilleries and anthracene works, and
40 works for the manufacture of lubricating oils.

The personnel of the factories consisted of day workers engaged in discharging and breaking pitch. The fact was established that, in consequence of neglect or ignorance of the instructions laid down by the management, the uncovered parts of the skin most exposed to the action of sunlight, as well as the eyes, were, during the hot season, affected even after only a few hours' work. Blonds were affected most (66.4 per cent. — Lewin). The malady took the form of an acute erythema, with characteristic pigmentation due to tar. After the lapse of some weeks or months, the workmen presented, in different degrees, the melanosis characteristic of the face and upper limbs, with inflammation of the conjunctiva, etc.

In the United States tar lesions, especially of a cancerous nature, are little met with. In 1914 B. F. Davis reported a case of cancer in a workman employed in a refinery; in 1921 McCord and Kilker examined 17 workmen engaged in impregnating wood with tar, creosote and zinc chloride. The lesions formed were (a) tar dermatitis resembling dermatitis venenata, and were attributable partly to benzene, to the light oils, and to the various distillation products (2 cases); (b) tar acne, in differing degrees, in almost all those examined and due to accumulation of tar in the hair follicles especially of the forearm; (c) tar cancer localised on the forearm or scrotum (2 cases).

In France the cases are not numerous. Nevertheless from time to time observations of cases are reported; thus, for example, the "devillers", i.e. workmen engaged in breaking up the coke residues
### CASES OF EPITHELIOMATOUS ULCERATION REPORTED IN GREAT BRITAIN BETWEEN 1920 AND 1927

<table>
<thead>
<tr>
<th>Injurious substances</th>
<th>1920</th>
<th>1921</th>
<th>1922</th>
<th>1923</th>
<th>1924</th>
<th>1925</th>
<th>1926</th>
<th>1927</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tar and Pitch:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Briquette factories,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(&quot;patent fuel&quot;)</td>
<td>30</td>
<td>17</td>
<td>19</td>
<td>14</td>
<td>11</td>
<td>25</td>
<td>27</td>
<td>20</td>
<td>163</td>
</tr>
<tr>
<td>Tar distilleries</td>
<td>4</td>
<td>9</td>
<td>6</td>
<td>14</td>
<td>15</td>
<td>23</td>
<td>18</td>
<td>14</td>
<td>103</td>
</tr>
<tr>
<td>(tar and pitch)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas works</td>
<td>4</td>
<td>4</td>
<td>21</td>
<td>6</td>
<td>12</td>
<td>9</td>
<td>15</td>
<td>14</td>
<td>52</td>
</tr>
<tr>
<td>Various (tar, pitch,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>creosote, anthracene)</td>
<td>4</td>
<td>2</td>
<td>—</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>16</td>
<td>10</td>
<td>44</td>
</tr>
<tr>
<td>Paraffin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shale oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral oils</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mole spinning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other industries</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>45</td>
<td>32</td>
<td>33</td>
<td>58</td>
<td>122</td>
<td>160</td>
<td>174</td>
<td>219</td>
<td>811</td>
</tr>
</tbody>
</table>

The raised figures refer to deaths.

* One of the two fatal cases was notified in 1923 and the fatal issue occurred in 1924.

### Manipulating Blast Furnace Tar and Pitch

Manipulating blast furnace tar and pitch, finding that pitch of this nature does not possess the same carcinogenic properties as that from coal tar. Since epitheliomatous ulceration was made compulsorily notifiable in 1920 no case has been reported from contact with blast furnace tar. These observations have been confirmed experimentally by Leitch.

On the other hand, the pitch from coke ovens and gas works used in briquette manufacture is responsible for more than a half of the notified cases. As a matter of fact, of the 95 cases reported between January 1920 and June 1922, 66 were due to pitch.

It is interesting, further, to see, from the British data, what is the situation of these tumours. Between 1920 and 1923 in 100 notified cases (with 110 cancers) due to pitch, and 33 cases (with 34 cancers) due to tar, the situation was as follows:

<table>
<thead>
<tr>
<th>Pitch</th>
<th>Tar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scrotum</td>
<td>27</td>
</tr>
<tr>
<td>Scrotum and penis</td>
<td>1</td>
</tr>
<tr>
<td>Penis</td>
<td>1</td>
</tr>
<tr>
<td>Scrotum and other places</td>
<td>4</td>
</tr>
<tr>
<td>Head, neck, ear</td>
<td>11</td>
</tr>
<tr>
<td>Face (nose, chin, etc.)</td>
<td>7</td>
</tr>
<tr>
<td>Eye and eyelids</td>
<td>11</td>
</tr>
<tr>
<td>Cheek</td>
<td>14</td>
</tr>
<tr>
<td>Lips</td>
<td>13</td>
</tr>
<tr>
<td>Upper limbs</td>
<td>8</td>
</tr>
<tr>
<td>Lower limbs</td>
<td>2</td>
</tr>
<tr>
<td>Arms, leg and cheek</td>
<td>1</td>
</tr>
</tbody>
</table>
According to Kennaway, these 144 cancers produced by tar and pitch among 133 persons (1920-1923) may be classified as follows in percentage figures (value in percentage):

4: fingers, leg, foot and toes;

88: scrotum, penis, head, face, eye, eyelids;
13: arms and hands.

The cases notified between 1920 and 1927 among workmen coming into contact with tar and pitch were situated, according to Bridge and Henry, as follows:

<table>
<thead>
<tr>
<th>Briquette factories (&quot;patent fuel&quot;)</th>
<th>Tar distilleries</th>
<th>Gas works</th>
<th>Other industries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>Per cent.</td>
<td>Total</td>
<td>Per cent.</td>
</tr>
<tr>
<td>Scrotum</td>
<td>28</td>
<td>11.0</td>
<td>41</td>
</tr>
<tr>
<td>Head and neck</td>
<td>115</td>
<td>71.2</td>
<td>39</td>
</tr>
<tr>
<td>Arms</td>
<td>11</td>
<td>6.7</td>
<td>18</td>
</tr>
<tr>
<td>Legs</td>
<td>1</td>
<td>0.6</td>
<td>1</td>
</tr>
<tr>
<td>Other situations</td>
<td>7</td>
<td>4.3</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>163</td>
<td>100</td>
<td>103</td>
</tr>
</tbody>
</table>

The duration of employment of the workmen affected by tar and pitch cancer according to Bridge and Henry was:

<table>
<thead>
<tr>
<th>Duration of employment</th>
<th>Briquette factories</th>
<th>Tar distilleries</th>
<th>Gas works</th>
<th>Other industries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 10 years</td>
<td>9</td>
<td>9</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>From 10 to 15 years</td>
<td>25</td>
<td>19</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>From 16 to 20 years</td>
<td>28</td>
<td>9</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>From 21 to 30 years</td>
<td>50</td>
<td>23</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>From 31 to 40 years</td>
<td>19</td>
<td>17</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>From 41 to 50 years</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>From 51 to 60 years</td>
<td>1</td>
<td>1</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Not stated</td>
<td>29</td>
<td>19</td>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>

Among the various industries in which tar or pitch cancer was reported were cable manufacture (4); net making (2); ship repairing (2); tarring felt (2); bituminous painting (1); brush making (1), etc.

In 1924 the notification of one case led to an enquiry which brought to light 3 other cases of epitheliomatous ulceration of the scrotum. A voluntary examination organised by the employers brought to light one case which underwent immediate surgical treatment. In the same year Henry examined for skin disease 24 workmen employed for from fourteen to forty-two years in handling tar. He found 7 cases of folliculitis; 4 of sebaceous cysts; 6 of warts; 4 of epitheliomatous ulceration; 2 of ulceration of the cornea and one each of keratosis and dermatitis.

In Italy Lazzarini, in 1928, described a case of epithelioma of the skin on the back of the hand in a workman who had been employed for thirty years in a tar distillery. This was the second case of tar cancer reported in Italy.

In Switzerland the National Accident Insurance Fund had knowledge of the following cases of poisoning: 1919, 1; 1922, 2; 1923, 1; 1924, 2; 1925, 1; and of ulceration of the skin: 1921, 2; 1923, 3; 1924, 6; 1925, 8.

### Pathology

The workmen in tar distilleries are exposed to a variety of accidents and diseases.

The accidents are due principally to the inflammability and danger of fire from the tar and distilled oil. The vapours of tar oils as well as the gases given off at the commencement of the distillation are readily inflammable, and even explosive, when mixed with air. Serious accidents have taken place in Germany — one in 1893 from a gas explosion, the other in 1895 from the naphthaline vapour catching fire. The explosion of tar dust, during breaking, caused a fatal accident in 1897.

Boiling over and splashing of the hot oils, phenols, acids and alkalis used for the purification of the light oils cause burns. These similarly may be produced by the tar or pitch while still hot, especially if they are discharged into receptacles still containing water, the sudden development of steam causing violent spurring. In 1903 a fatal accident was caused in this way by allowing boiling tar to flow into a receptacle still moist. In 1910 a similar accident occurred when the distillation residues were received into a receptacle (Germany).

A great danger is due to the fact that the work clothes become impregnated with tar oils which may burst into flames if the workman wearing them approaches a fire. Two fatal accidents occurred from this cause in Germany — one in 1904 and the other in 1910.

The disease most prevalent among the tar workers is dermatitis; it occurs among them even to a greater extent than among paraffin workers. Neu-
mann, of Vienna, turned his attention in 1876 to the acne produced by tar and paraﬃn. Leaur was the first in 1883 to describe the acne due to the oils used in the textile industry. Purdon a little later and Reid in 1898 described cases of acne due to the same cause.

Melanosis from pitch was described by Oscar Ehrmann, who, in 1899 and 1910, showed the development of comedones and hyperkeratosis on the palm of the hands of the workers. Bader in 1911 described cases of melanosis and acne of the face; Schraenger in 1912 described chronic lichen planus and occurrence of cancer.

It ought at once to be admitted that all authorities are at one in recognising the closeness of the clinical picture of the lesions set up by paraﬃn, pitch and tar, it being granted that the cause — still undiscovered — is probably the same.

Along with the keratoplastic action may be played the photo-dynamic action of certain substances present in the tar and pitch which render the skin more sensitive to the action of luminous rays. Among the substances in question are thiazine, thiazone, azines, etc., to which attention has been directed a special mention should be made of acridine.

The skin of the face, arms, trunk, and, generally, of the uncovered parts of the body, becomes the seat of an acute or subacute inﬂammation followed by eruptions, folliculitis, warts, comedones, and patches of “shagreen” coloration of the skin. Bollmann classiﬁes these lesions under four heads: folliculitis, slow and often pruriginous “diﬀerential diagnosis: tuberculosis”; follicular keratosi (diﬀerential diagnosis: pityriasis rubra pilaris, psoriasis, Darier’s disease); melanoderma of the palms exposed to the action of light “diﬀerential diagnosis: Addison’s disease, arsenical melanosis, pigmenta- tion following ichen ulcer plants”; circumscribed warty patches “diﬀerential diagnosis: lupus erythematosus.” Nearly always two or more of these lesions are found associated on the same subject, which facilitates the diagnosis.

Cases of melanoderma, toxic ichenoides and bulla of Hoffmann due to tar have been described by Kismeyer, Mieowski 1925, Freund 1926, etc.

The vapours emanating from the ﬂoors more or less impregnated in the course of tar distillation in 1883 in warm weather, and in persons particularly sensitive, to an intense and disagreeable pruritus of the face; this is always accompanied, in a case observed by Leymann, by erythema of the face and violent oedema of the nose. These unpleasant features, due perhaps to acridine, may be so severe as to compel sensitive persons to give up the work, but the majority of the workers pay no attention to them.

The cancerous degeneration of the warts and ulcers of the skin among the tar workers is well known. Volkman in 1875 and Tilmannus in 1889 have carefully studied tar workers and have been reported recently in a work- man engaged in road tarring O’Donovan, in workmen in a factory for tarring paper 3 cases, Schumperl, 1910, etc. Heuer 1923 collected 50 cases of cancer scattered throughout medical literature.

The striking diﬀerence noted in the incidence of tar cancer in the diﬀerent countries seems to depend on the kind of coal used and consequently on the composition of the tar and pitch so derived. The compounds coming from the oily coals (Great Britain, Belgium) seem to be the most injurious; tar and pitch coming from blast furnaces would seem to be only slightly carcinogenic, and those from coke ovens appear to be less harmful than those from gas works (Courmont). Kenaway, who has studied systematically the diﬀerent compounds in tar, with the object of identifying that element which is responsible for the cancer, is led to think that the carcinogenic substance is still unknown, unstable and present in minute quantities — perhaps as elusive as vitamins in food. His enquiries among tar workers tend to show that the carcinogenic factor is present in the fractions which distil over between 230° and 500° C. (creosote, anthracene and their constituents, pitch). Experiments conducted for the purpose of determining, among the compounds known to come over at a high temperature, that one or those capable of producing cancer, have yielded only negative results. The substances which are known to exist in the tar have been isolated, but have not thrown light on the problem, at least on the experimental side. The unknown substances, few in number and unstable, which do not form well recognised compounds, might contain this or those with carcinogenic quality.

Emphasis must be laid on the importance and extent of the experimental investigations on tar cancer commenced by Fischer. At the moment the long series of experiments to give up tar enable one to say that if every diﬀerent cause can produce experimental tar cancer, the same causes, acting in the same conditions, do not always set it up. This emphasises the importance played by the soil “constitution” in
COAL TAR

experimental and human tar cancer. In 1925 Peyre and Kozareff showed that tar electrolysed from the negative pole (positive charge) enables a cancerous condition to develop more rapidly or, at any rate, more completely than by employing tar from the positive pole (negative charge) or ordinary tar.

Finally, there are some authorities who regard tar cancer as too identical with that produced by arsenic for any doubt to exist that it is this product, present very frequently in coal (see article "Tumours of Occupational Origin"), which sets up the condition. As a matter of fact, vegetable tar, which contains no arsenic, has never caused cancer and it is even employed as a local remedy in Northern Africa and the Levant. Others again consider that tar may have radio-active properties and from this source derives its carcinogenic action (Lewin and Schamberg). Bloch, who has also studied this aspect of the question, lays stress on the fact that certain tars only contain the specific substances capable of irritating the skin, and that their presence can be proved in different quantities in certain fractions of the distillation. It would then not seem to be a question of one sole substance, but of several carcinogenic substances coming off in the fractions between 200 and 350° C. at ordinary pressure, and in the case of certain tars, higher fractions. The toxic specificity is, however, relative, because the carcinogenic action of these substances varies according to race, individual, organs, etc.

The question of whether the carcinogenic action can, generally speaking, be regarded as identical with the irritating action of the skin, or at least whether these two actions go along parallel lines, would appear to be settled in a positive sense from the numerous experiments and clinical observations.

For many years a summation of irritating action has been admitted of the irritation set up by the substances handled in the mineral oil and tar industries, causing in some persons slight, in others severe, dermatitis, which takes on in certain individuals precancerous conditions favoured as regards their development by external and internal influences, and lastly cancer.

So far as the clinical picture is concerned authorities are consistent, as to the site, of certain very important differences between tar and paraffin cancer. The latter is most often situated on the upper members, forearms and on the scrotum. Tar and pitch cancer is situated especially on the face (eyelids, cheek, nostrils (Bang, 1923), ears, forehead), sometimes on the arms, exceptionally on the other parts of the body, especially the genital organs. No difference exists between these tumours in the matter of their development. But tar does not present so many cases of multiple cancers as does pitch.

Implanted on ulcerating warts the condition may remain stationary for a long time. Extension in depth is very rare and so too is the case as regards metastasis. The most malignant tumours are those situated on the scrotum.

It would be interesting to observe the workpeople in tar, paraffin and pitch, etc., works to see if tumours develop a long time after they have ceased work. Thus Roesch (1923) has reported a fatal case of cancer (lungs, stomach, arms) who had done nothing but open-air work for seventeen years after having left the paraffin factory where he had been stationed, the fact that a certain tar does not present a carcinogenic action (Lewin and Schamberg). Bloch, etc.) and on the cornea. Cases of blepharitis, eczema, tattooing of the cornea and Baer have described a localised tumour on the lower eyelid. Cases of eczema of the external ear have been described.

Tar dust and fumes have evidently an irritating action on the respiratory tract, but precise data are lacking to determine whether a carcinogenic action on the lungs takes place. No effects due to tar have been noted on the teeth or the mouth.

Some authorities take the view that tar can set up a general intoxication; they have described how persons exposed to the action of tar fumes suffer from headaches, nausea, vertigo, loss of appetite, albuminuria, dysuria, strangury, and even exhibit the picture of pernicious anaemia (Heubner). It is questionable though whether other products of distillation are not responsible for a more important role in producing these symptoms than tar. Experimentally also Davidson has produced cirrhosis and necrosis of the liver.

In the use of anti-rust paints with a tar basis the vapours given off from the light and heavy oils and the varnishes in confined spaces and particularly the vapour of benzene, toluene, and xylene, etc., are said to be the cause of the vertigo, nausea, weakness,
and muscular inco-ordination, and cyanosis, etc., complained of. Berg has reported (1928) a case which is perhaps the first of the kind described in medical literature: a young man who had worked for three weeks in a tar distillery was seized with coryza, dyspnoea, migraine, nausea, lacrymation and vertigo so severe as to compel him to give up his work. After taking it up again later he was again obliged to abandon it. Experiments carried out in Berg’s clinic brought out the fact that in him (but not in seven other patients) typical anaphylactic attacks resembling those he had suffered from could be produced spontaneously. Coal tar, therefore, must be regarded, when inhaled in the form of vapour, as capable of provoking in some persons attacks of migraine uncontestably anaphylactic and thus similar to the asthmatic seizures set up by ipeccuanha. Albuminous substances consequently are not alone in being able to set up attacks of an anaphylactic nature. (For the other tars, see articles “Poisonous Woods” and “Lignite.”)

The poisonous gases and fumes coming off in the course of different industrial processes or from the substances obtained from the distillation of tar (see the article in question) must be regarded as sources affecting health. It should be remembered once for all that, especially in the industry in question, it is very difficult, if not impossible, to identify the substances which are the cause of the damage. Nor does one find oneself anywhere else in the presence of such a complex mixture of gases: hydrocarbons, sulphur compounds, cyanogen, carbon, arsenic, etc.

In addition, the reports received do not show exactly which product was probably the cause of the lesion. Mention is made of tar, pitch, mineral oils, benzene, etc., without any precise data enabling the offending substance to be identified.

The dust, generally hot, the splashes of liquid, the pasty substances, the heat, etc., are all causes of injuries playing a very important role in the industrial pathology of work in the distillation of tar.

**Hygiene**

Premises for obtaining tar of different kinds are in many instances unsuitable: fire risk (from tar, mineral oils, etc.); unpleasant smells; evolution of sulphuretted hydrogen gas; production of ammoniacal and sulphurous liquids, etc.

Such works, therefore, should be at a distance from human habitations; they should be of incombustible materials; workrooms should be separate from storerooms; the floor should be constructed of impermeable materials and sloping to a central drain, etc. The ventilation of the workrooms should be ample. The tar should be kept in metal containers or in wooden barrels encircled by iron bands, or better still in airtight receptacles. The stills should be charged by means of pumping apparatus. The volatile liquids should be condensed in closed vessels, the apparatus being the distillation apparatus built of masonry a sufficient space should be practically possible be separated by a massive wall from the rooms in which the distillation products are recovered. For distillation apparatus built of masonry a sufficient space should be arranged for underneath to hold the contents should it explode.

Entrance into the workrooms with a light should be prohibited. There should be good natural light; artificial light should be arranged by means of lamps placed outside and separated from the workroom by a further glass surround. Contact breakers and fuses should be outside the room. Effluents should be neutralised before being discharged into the sewer. Pitch should be removed from the stills by a tap or pump having its discharge point outside the workrooms. The extracting tank should be placed under a hood conducting the fumes into a tall chimney. The danger of fire should be considered carefully at the time the works are built. Rooms in which firing is necessary or those in which sparks might be emitted should be separate from other premises, and arranged so that it should be impossible for fumes or gases to come from the premises into the premises of distillation, especially when given off in quantity, as, for example, when the cooling apparatus breaks down, or the distillation apparatus boils over. The firing of the stills should where practically possible be separated by a massive wall from the rooms in which the distillation products are recovered. For distillation apparatus built of masonry a sufficient space should be arranged for underneath to hold the contents should it explode.

Soft sand should be placed in readiness against outbreaks of fire.

Workmen should avoid working in the sun. Diffusion of tarry dust should be prevented as far as possible. Personal hygiene (such as provision of working clothes, goggles, etc.) should be encouraged. At the same time the question may be raised whether too frequent washing of the hands does not favour occurrence of dermatitis amongst workers in contact with tar (A. H. Lush). The German Coal Syndicate recommend their workmen to smear their faces and forearms with a mixture of...
oxide of zinc and talc (100 grm.), glycerine and water (200 grm.). Workmen are accustomed to daub fuller's earth or chalk on their faces. In Germany the proposal is being made of using, in the manipulation of pitch and tar in powder form, certain types of machines in order to reduce the danger of contact with these substances to a minimum.

No person should enter reservoirs, tanks or tar stills until the receptacles have been sufficiently blown out with steam under pressure. Even then the workman should only enter with a safety rope round the waist and with someone outside to watch all the time.

Work in narrow stills, often furnished with agitators, is rendered difficult because of the close confinement. Such work, being as it is one of the hardest and most dangerous, should not be permitted until the receptacle has been sufficiently cooled. It should be recalled that the caking of the pitch coke covering the internal walls of the stills emits emanations which can sometimes involve serious dangers to the health of the workmen.

A naked light should never be used in stills, etc. (danger of fire and explosion). Use must be made of electric lighting in premises containing explosive material (isolation of the lamps and wires by material such as will resist the derterious effect on them of the tarry oils and their emanations).

The workmen should not stay longer than ten minutes in the stills and on coming out should change their clothes. These, soiled as they are by tar oil, should not be worn again, except after careful cleaning.

To ensure the evacuation of the poisonous fumes at the commencement of distillation the ends of the pipes in the apparatus should be U-shaped and connected up with the highest part of the closed canalisation system by which the gases are eliminated. Their purification should be carried out by means of lime and oxide of iron. If the distillation is carried out under pressure the toxic vapours will be drawn away with the air which, after passing through the fan, should be neutralised so as to prevent the gases penetrating into the workrooms and setting up poisoning there.

**LEGISLATION**

The employment of women and children is governed by the same regulations as control the chemical industry. It should be recalled that in Belgium young persons of less than sixteen years of age are prohibited from work in the distilleries.

In Canada boys of less than sixteen and girls of less than eighteen are prohibited from dipping iron pipes and wood in tar. In France, young persons of less than sixteen years are prohibited from work in tar distilleries. In Italy, boys of less than fifteen years and girls of less than twenty-one are prohibited from work in places where tar is distilled, etc., etc.

In Great Britain the Factory Inspection Department of the Home Office made recommendations (Form 919) as to the employment of workmen engaged in tar distilling.

Notification of chronic dermatitis, ulceration of the skin and skin cancer due to tar is compulsory in France, Great Britain and Russia.

Compensation of the same conditions is provided for in Germany, Great Britain, Austria, Switzerland, Finland (coal and wood tar).

It is laid down also in Western Australia and Queensland (skin and corneal ulceration), in the States of Minnesota, New York and Ohio (skin and corneal ulceration), in Japan and in countries where compensation for all defined maladies is admitted statutorily. (See also article "Industrial Diseases — Compensation").

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"O. H. Leumann"

(Berlin).
Cobalt

French: Cobalt. — German: Kobalt. — Italian and Spanish: Cobalto.

Properties

Cobalt (symbol Co) is a metal of silver white colour, malleable when heated, and brittle when cold; it melts at 1,478° C. and has a specific gravity of 8.8; its degree of hardness is 5.5. It is magnetic and is unaffected by air; it dissolves in mineral acids even when they are diluted; in concentrated acids it gives blue solutions, which become red on dilution with water.

Production — Uses

Metallic cobalt is obtained either by roasting its ores (e.g. smallite, arsenide of cobalt (Co As₄), or grey cobalt, sulpho-arsenide of cobalt (Co ASS), or siegenite, sulphide of cobalt, or asbolite, arsenate of cobalt hydrate, ores which frequently also contain nickel) or as a secondary product in certain metallurgical processes, especially from the cobalt-silver bearing ores of Cobalt, in Ontario, Canada.

The ores are roasted in order to get rid, as far as possible, of sulphur and arsenic; the oxide obtained is transformed into metal by reduction with carbon or hydro-gcn.

At Cobalt, the ores after separation of the silver are subjected to treatment for extraction of the cobalt, which is dissolved in certain solvents for separating the nickel, iron and copper. Then it is precipitated from the solutions in the form of oxide and reduced to metallic cobalt, as mentioned above.

The ores of cobalt were formerly used for preparing the oxide which was used in the making of colours, enamels and the salts of cobalt. To-day it is used chiefly in the preparation of certain kinds of very strong steel and alloys, of anodes for the electrolysis of alkaline electrolytes (among cobalt is not affected by alkalies), for nickeling other metals, for colours, enamels, and for the manufacture of a certain kind of glass.

The salts of cobalt are red in aqueous solutions, or when they are crystallised; they are, on the other hand, blue in aqueous solution with concentrated hydrochloric acid; in the anhydrous state they are blue, yellow, or green.

Sources of Danger — Pathology

Among the dangers which cobalt presents in the course of its extraction, one must note risks of poisoning from sulphuretted hydrogen, which is liberated — although in minute quantity during the roasting, from carbon monoxide during the melting and from arsenic when the ore treated contains this product.

It is important to bear in mind here the incidence of tumours of the lungs found among the miners of Schneeberg (Saxony), who are employed in the extraction of smallite or arsenide of cobalt.

The miners of the Erzgebirge, who work cobalt, have been aware for a very long time that their health is exposed to grave dangers. Paracelsus and Agricola — the latter the earliest German geologist, as well as a doctor — were acquainted with the chronic disease of miners, known as "miners' phthisis". A pupil of Agricola, Martin Pansa, a doctor of the town of Annaberg, pointed out that mercury, pyrites, cobalt, and other metals may liberate poisonous vapours.

Cobalt or "cobold", which is another name given to the ore, formerly not put to any use, was found in the silver mines. This ore only came to be worked from the time when the manufacture of blue colour by means of oxides of cobalt was invented.

The district of the cobalt mines of Schneeberg, which lies in the western part of the Erzgebirge, since the working of silver ceased, came to be the site of a once prosperous industry for blue colours. Ores of cobalt and nickel are found there in the form of arsenides of cobalt (smallite) and of nickel. A great part of the cobalt and nickel is recovered by iron and a small part of the arsenic by sulphur.

Cases of cancer of the lungs were numerous some centuries ago and are still seen to-day among the miners of the district of Schneeberg, where the working of bismuth has become more important than that of cobalt; they cannot be attributed only to the inhalation of cobalt dust.

Hesse and Hartig (1878-1879), who were the first to determine the malignant character of the disease of Schneeberg, emphasised rightly the inhalation of dust as a factor in causing the disease, attributing the principal role to arsenic. The value of this theory has undoubtedly been proved by more recent evidence.

Osler, on the other hand, attributed the frequency of pulmonary carcinoma to the action of cobalt. In 1884 Aranke devoted his doctorate thesis to this question, and in 1912-1913 Arnstein, in his turn, studied the problem. Following a personal investigation, this latter expert emphasised that out of 44 per cent. of cases of death attributed by local doctors to malignant growths of the lungs, not one had been confirmed by autopsy. He examined 70 miners,
among half of whom he was able to find signs of parasternal and para-vertebral dullness. He was only able to carry out two autopsies, of which one proved that death was due to a caseous tuberculosis and the other to a carcinomina of the lung.

The miners described by Thiele, Rostoski, Saufe, and Schmori have dealt with 143 miners, diseased or not, 176 workers at the blue colour factory of Oberschlema, and 120 persons selected from the population. These experts have been able to agree that the disease in question was characteristic of miners. According to Saufe, 20 out of the 143 miners showed clearly a radiographic picture of a pathological condition of the lungs: 4 tuberculosis, 17 pneumonoconiosis and 8 of tumours. Rostoski admits the existence of an etiological relation between pneumonoconiosis and tuberculosis, a relation which had previously been recognised by M. Uhlig. He considers that the irritant is arsenic, which is capable of leading to the formation of the tumour while it would prevent, within a certain limit, the development of tuberculosis. Rostoski, who had previously been recognised by M. Uhlig, and found carcinoma with anthracosis more or less serious, has not gone as far as to pronounce on the capacity of arsenic to be cancer-forming.

It is beyond question that the chief factor is represented by the inhalation of dust. The analysis of the various kinds of dust gives the following results: silicic acid, 50 per cent.; alumina, 14.65 per cent.; ferrous oxide, 7.50 per cent.; oxide of calcium, 12.85 per cent.; smaltine or arsenide of cobalt, 0.19 per cent.; nickel cobalt, 0.08 per cent.; losses, 9.8 per cent.

It is estimated that the miner can inhale each day several milligrams of arsenide of cobalt. Fungus growths are also found in the mines, which have the property of forming diethylarsine in the presence of arsenic. The hypothesis has been recently put forward that the various kinds of dust can exercise a radioactive effect on the pulmonary tissues. As a matter of fact, the radio-emanations are very intense in these mines, for in the water of the mines is found the proportion of as much as 70 Mache units per litre.

Among the other predisposing factors should also be mentioned defective feeding of these miners, diseases of the pleura and lungs, laborious work, and risks from exposure to cold after heat.

Among the symptoms caused by tumour of the lungs, Haerting and Hesse detail painful points in the thorax, a troublesome cough with expectoration, pallor of the face, and an atrophic skin, parasternal and paravertebral dullness, diminution in the movement of the thorax, difficult respiration, and sometimes dyspnoea. Diagnosis is very difficult, especially at the beginning of the affection, and it can only be made by the help of radiography.

The course of the disease is fatal in a period of time varying from 6 to 18 months, or even more. At the autopsy is found a slight effusion in the pleural cavity with adhesions; the affected lung is retracted and pushed back by the tumour. Generally, there is a simple carcinoma; occasionally, one meets with lymphosarcoma, multiple carcinomata of the bronchial glands, of the pleura, and still more rarely of the pleura.

The disease generally affects miners who have worked in the mine ten or twenty years or more. It attacks mostly the hewers, then the workmen employed as masons in the galleries, and the labourers.

Nothing is known of injury caused by cobalt or its salts due to the use of colours or alloys containing these products. The ammoniacal compounds of cobalt have, according to Bock, a toxic action similar to that of curari.

There was noticed for a time amongst workers in a cobalt foundry in the Hildesheim district (Germany) the occurrence of localised dermatitis, especially of the genital organs. These lesions, which were attributed to the action of arsenical compounds, developed during roasting of the ore (arsenical compounds of cobalt) and disappeared after the workers had been provided with working clothes, and measures of cleanliness were more strictly enforced. (Report of the German Inspectorate for 1923.)

Margain also pointed out in 1905 that the men employed in washing ores of cobalt often suffer from hyperkeratosis of the palms of the hands and holes in the skin, especially at the level of the metacarpophalangeal articulation, due to the handling of the tools. These lesions develop rather rapidly into superficial ulceration, which appears as a dry crateriform ulcer.

The disease of the lungs of Schneeberg miners is compensated by German legislation.

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Cocaine

French: Cocaine. — German: Kokain. —
Italian and Spanish: Cocaina.

Coca, a species of the genus Erythroxylum, is a shrub native to the Andes where it grows in a wild state in the regions between 700 and 3,000 metres high. It was then cultivated in the different States of South America and imported into the East (India, Ceylon, Indonesia, and Oceania).

Peru was for a long time the sole producing centre, where from the earliest times this sacred plant was used as a certain remedy for all ills. The amount consumed wild is considerable, for the natives chew constantly a mixture of coca leaves and slaked lime or "Kipla" (made from the ashes of certain vegetables).

Coca is used as it is as a therapeutic agent, but it serves especially for obtaining cocaine. This was for a long time a monopoly of Peru, which was lost subsequently by the competition of other countries and mainly by the manufacture of synthetic cocaine.

The extraction of cocaine from the leaves is done on the gathering ground ("cocal"), where the planters set up their very crude works.

The whole leaves, dried previously in the shade, are placed in wooden macerating vats containing water slightly acidulated with hydrochloric or sulphuric acid (1-2 per 1,000).

The acid solution drawn off is treated with a slight excess of lime or carbonate of soda. The cocaine is precipitated and the alkaline liquid obtained is immediately covered over with a layer of 3-4 cm. of petrol, which dissolves the cocaine set free by the alkali. Any agitation of the liquid must be avoided at all costs in order to prevent the introduction of air which would render the process nugatory. By means of great discs of wood moved alternately up and down, the lower layers of the liquid holding the cocaine in suspension are slowly brought into contact with the layer of petrol. As will be understood, the process is long and arduous. When the cocaine has been extracted, that dissolved by the petrol is purified by a further acid extraction and second precipitation. The cocaine obtained amounts to 78 to 89 per cent. This crude process has been modified either by a more complete treatment of the leaves, or a preliminary grinding of them in order to triturate them (a procedure which shortens the duration of extraction), or by digesting them with acidified alcohol. The tincture with milk of lime added is decanted, neutralised by sulphuric acid, and the alcohol is distilled. The extract obtained yields, on treatment with water, the hydrochlorate of cocaine. Other processes have been tried (Lorsen process, etc.) which convert the crude cocaine into the hydrochlorate; others make use of the fact that the impurities in crude cocaine are salts of ecgonine, which can be converted into cocaine. The crude substance treated by boiling with hydrochloric acid yields hydrochlorate of ecgonine, which is separated by nitration and purified by successive crystallisations. It is dissolved in methyl alcohol and saturated with gaseous hydrochloric acid. The hydrochlorate of methyl benzoil ecgonine obtained is precipitated by ether, treated by benzoil chloride and thus converted into methyl benzoil ecgonine hydrochlorate, which is the same thing as hydrochlorate of cocaine.

To-day cocaine is manufactured in a state of great purity by several processes, using ecgonine as a starting point. Cocaine is often replaced by slovajne, which is a hydrochlorate of amylene. The dimethylaminoacetone, obtained in making chloracetone react on dimethylamine, is treated with the Grignard reagent to obtain methyl benzoyl ecgonine, which is converted into methyl benzoyl ecgonine hydrochlorate, which is the same thing as hydrochlorate of cocaine.

Coca possesses an action analogous to that of coffee, betel, tobacco, etc., and it is well known how it enables an individual to bear great fatigue without food for a certain time and up to a certain point. But its abuse has very serious drawbacks, which are noticeable among the Indians working in the mines who chew coca leaves day and night. The well-known ill-effects set up by the abuse of coca have been observed in certain persons who "taste" coca (nervous troubles, anaesthesia of the tongue, etc.).

In industrial use no cases of cocaine poisoning have been reported.
COCAINE

symptoms described among the work-
men are generally attributable to the
substances used for the extraction and
manufacture of the alkaloid in ques-
tion. On the other hand, cases of
dermatitis are described among medical
men using it as an anaesthetic.

Cases of dermatitis of professional
origin among dentists and ophthalmo-
ologists have recently (1921-1925) been
reported from procain. The clinical
picture and the development of these
dermatites recall very closely the cases
of dermatitis from dichloramine and
asphenamine. The dermatitis causes
intense itching, the inflammation is
more keratotic than vesicular; some-
times rhagades are found and the nails
are often affected. Under the nails of
the thumb, index and middle finger of
both hands a very painful hyperkera-
tosis, yellowish in colour and very
painful, is often found recalling the
analogous lesion to be seen among
naphthaline workers. This lesion has
been described by Spillmann and
Mongoll (1925) as affecting a dentist
and ophthalmologist. Lane (1921) has
studied three cases of dermatitis from
cocaine and similar appearances follow-
ing on the use of novocain.

Injury set up by alkaloids are com-
pensated in Switzerland.

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Cochineal

Dried cochineal is used in the dyeing
industry in the manufacture of carmine
and ammoniacal cochineal. The latter
is found on the market in tablets and
in a paste form, and is prepared by
making ammonia react on pulverised
cochineal.

Workers and people in the neigh-
bourhood suffer inconvenience from the
smell of ammonia.

Hygienic measures include ventila-
tion of the workshop; keeping closed
all openings giving on to public high-
ways, luting of apparatus and of re-
cipients containing ammonia and
cochineal, installation over the con-
densation apparatus of hoods com-
muicating with chimneys with strong
exhaust, and, where advisable, con-
densation of the ammonia in water
strongly acidulated by means of sul-
phuric acid.

Codeine

French: Codéine. — German: Kodein. —
Italian and Spanish: Codetina.

Codeine is an alkaloid of opium
obtained as a by-product in the extrac-
tion of morphine. It is also produced
by synthesis in methylating morphine
(see article "Opium").

Goldberg and Leitis (1926) found
several cases of poisoning in a Russian
factory where codeine was being pre-
pared by treating sulpho-chloride of
toluene with methyl alcohol. One
worker particularly had been severely
poisoned in 1924. She had been en-
gaged in heating the chloride and filter-
ing the methyl ether from paratoluol
sulphonic acid; two days afterwards
redness of the hands appeared, extend-
ing to the shoulders, then oedema, and
later violent headache and shivering.
The arms were covered with red
blotches and papulæ, etc., which re-
curred when the worker returned to
the factory after a month's absence on
sick leave. Five other similar cases,
though less severe, were reported from
the same factory where certain pro-
cesses seem at any rate to have been
carried out in a very primitive way, e.g.
hand labour in open vats, etc.

Low, of Edinburgh, is said also to
have described a case of dermatitis
from codeine in 1924.

Injury caused by alkaloids are com-
pensated in Switzerland.

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Colcothar

(Iron Oxide)

French: Colcothar; Oxide ferrique. —
German: Kolkolar; Eisenoxyd. — Ita-
lian: Colcothar; Ossido di ferro. — Span-
ish: Oxido de hierro.

Ferric oxide or sesquioxide of iron,
the formula of which is Fe₂O₃, is
found in nature in compact masses as
haematite or obligist and ochre earth. It is also obtained artificially in the form of a dull red powder known under the name of colcothar. English or Prussian red, rouge or oxide of iron prepared by calcining nitrate or oxalate of iron. The oxide obtained by roasting the sulphate, known under the name of English red, was formerly the residue from the manufacture of fuming Nordhausen acid.

The sulphate of iron or green vitriol dried on cast-iron plates is pulverised and introduced into retorts, where it is heated to redness. It is decomposed, thus yielding sesqui-oxide of iron, sulphuric and sulphurous dioxide. The first is collected to make fuming sulphuric acid, while a part of this anhydride, hydrated by the moisture remaining in the iron sulphate, yields sulphuric acid, which dissolves the excess of anhydride.

The second may serve for the manufacture of sulphuric acid or of sulphates. The residue from the retort is crushed, washed with water, and sieved.

Colcothar is used in the manufacture of certain paints, in polishing glass, and in the paste for making Swedish matches.

Colcothar is not toxic, and harmful effects in the course of its manufacture are caused especially by the acid gases produced: sulphuric and sulphurous dioxide, etc.

Measures of hygiene should take the form of removal of the factories from the neighbourhood of dwellings; impermeable floors; fireproof construction of the factory; calcination in reverberatory furnaces; installation of powerful ventilation; condensation of acid gases; and the drains; pulverisation of the material to be broken up should be done in well-ventilated dust chambers; material to be prevented when barrelling or bagging dusty material; locally applied ventilation should be installed at machines giving off dusts.

### Colocynthine

(Colocynth; Bitter Apples)

French: Colocynthis ; Colocyntine. — German: Colocynthinh; Colocynthin. — Italian: Coloquintide; Cononaro Amaro. — Spanish: Coloquintida.

Colocynthine is a bitter glucoside extracted from colocynth, the fruit of Citrullus Colocynthis Schrader (Cucurbitaceae).

Colocynth is gathered in Egypt, Asia, and Syria, where it grows freely. It is cultivated in Asia Minor, the Greek archipelago, Spain, and India. The round fruit is from to 6 to 8 cm. long, yellowish when ripe; the whitish pulp is bitter.

Colocynth is sold in the market in a peeled state, freed from its pits, and cut up. It contains a resin ("citrulline"), a bitter sugary alkaloid, and a small quantity of an essential oil. This fruit is used in medicine as a purgative in the form of powder, hydroalcoholic extract, and alcoholic tincture.

Colocynth inhibits the secretion of saliva and causes discomfort, vomiting, haemorrhagic diarrhoea, tenesmus, sometimes even nephritis and loss of consciousness with a fatal outcome (Barton). Janssens has described a case of poisoning affecting a workman who had removed the pits from 10 kg of colocynths, and suffered from the symptoms described.

### Compressed Air Work

(Work in Caissons)


Work in compressed air has to be done in all constructional work involving excavations in waterbearing strata, or under water, such as making tunnels, bridges, piers, quay walls, docks, dams, light-houses, etc., exceptionally in sinking mine shafts, as well as in all occupations involving diving such as sponge fishing, marine salvage work, etc.

Work in compressed air may be effected by a diver in a diving dress (see article "Divers") or by a group of workers, as in caissons. Divers without diving dress are exposed to injury analogous to the risks incurred by divers provided with diving apparatus and by caisson workers.

Though the Phoenicians had already used diving bells in 300 B.C., it was not until 1839 that the French engineer,
Triger, employed caissons to reach a coal bed under the Loire. A diving bell, however, had been used by Smeaton and Brunel for numerous operations in 1779. It is sometimes used still at slight depths.

**Technical Data**

Diagrammatically (fig. 38) a caisson consists of a working chamber (A), a shaft (B) which communicates freely with the above and an air lock (C). All these parts of the apparatus receive compressed air from a pipe (D). The part above the working chamber has to be lengthened and built upon, and it is the ever-increasing weight of this latter part which succeeds in driving into the ground the inferior extremity of the caisson as the work of clearing away progresses in the working chamber.

![Fig. 38. — Cross section of a compressed air caisson.](image)

The working of a caisson will be better understood by examining in detail the air lock. In older types (fig. 39) the communication between that and the shaft for descent is effected by a door (P₂) which opens from the foot, so that it is kept closed automatically by the pressure of the compressed air in the shaft and in the working chamber. On the other hand, it opens of itself when the two pressures are equal. The air lock is naturally provided with a door (P₁) which admits the workers into the caisson. This door, contrary to the manner of the preceding one, opens from outside inwards. Finally, the air lock is provided with two pipes: one (R₁) places it in communication with the shaft and the other (R₂) serves for decompression. A safety valve is installed with a view to avoiding a disaster should the compressed air pipe break.

![Fig. 39. — Air lock (old style).](image)

In the most recent types (fig. 40) the shaft is in direct communication with the upper chamber, one part of which only (C) is used as an air lock. What has been said above naturally holds good of this type also.

When work is in full swing, the working chamber and the shaft are under the same pressure and the door (P₂) is hermetically sealed. The worker who enters the air lock to go into the working chamber must carefully close the door (P₁), make sure that the decompression pipe is off, and open the compression pipe (R₂). The compressed air in the other two parts of the apparatus then penetrates the air lock and, owing to the compressed air continually emitted from the pipe, equilibrium is established between the air lock and the other two pressures. When this takes place the worker sees the door communicating with the shaft open automatically.

For evacuation of soil and debris the caisson is provided with two shafts, which receive the buckets and earth arriving from the upper part of the caisson by means of a sliding floor. A series of pipes brings each part of the cylinder alternately under the action of compressed air and that of the external air, and thus permits of evacuation of material without perceptibly altering the pressure. In large modern caissons the apparatus used for evacuation of rubbish and for laying of concrete are therefore independent of the
main shaft and air lock for the staff. Owing to the great weight of the caisson, precautions against tilting on one side and consequent loss of life are essential.

Compressed air work has undergone considerable development, thanks to the use of improved apparatus and equipment permitting of excavation at ever-increasing depths.

In the construction of tunnels through subaqueous strata, shafts are sunk through water bearing strata till they reach the stony bed. The caissons are constructed on the surface and later sunk to the sub-grade at the bottom of the shaft. The tunnel is excavated inside the caisson at the base of the shaft.

It is a well-known fact that man undergoes on the surface of the earth a pressure of 76 cm. of mercury (1 atmosphere), and he is not therefore very much affected by the slight increase of pressure which he may undergo when he has to work in the depths of the subsoil, as, for example, in mines. The question, however, assumes quite a different aspect when he is obliged to work under pressure which is artificially increased.

Within the caisson the air pressure must equalise the pressure exercised by the water, and it must in consequence be raised to a pressure which increases in proportion to the increase in the depth of the water which it is required to equalise.

At a depth of 10 metres (more accurately 10.33 metres), the pressure is therefore double the atmospheric pressure. It thereafter increases by 1 atmosphere for each 10 metres of depth reached.

The interior pressure of the caisson therefore depends on the height of the water in which it is submerged.

In the different reports there are met with continually the two expressions "gauge" or "plus pressure" and "absolute pressure". The latter is equal to gauge pressure plus atmospheric pressure.

In English texts pressure is generally expressed in lbs. or in lbs. per square inch. It is sufficient to recall that each square inch is subjected in the atmosphere to a pressure of about 15 lbs. or, more accurately 14.7 lbs., in order to understand that the pressure of 15 lbs. is equal to normal atmospheric pressure or to the pressure of 1 atmosphere.

Where the English text refer to "gauge" or "plus pressure" the expression used corresponds to pressure effective.

1 Instead of indicating the pressure exercised on the surface of the body in "atmospheres" it is often expressed in kilograms per square centimetre, given that, under normal conditions, the pressure stands at zero, for it is in equilibrium with the internal pressure. At a depth of 10 metres the body will, therefore, have to support a pressure of 3 kg., at 50 metres of 2 kg., with the result that the relation between the atmospheres and the kilograms is as follows:

<table>
<thead>
<tr>
<th>Atmospheres</th>
<th>Kg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>At the earth's surface</td>
<td>1</td>
</tr>
<tr>
<td>At a depth of 10 metres</td>
<td>9</td>
</tr>
<tr>
<td>...</td>
<td>30 ...</td>
</tr>
<tr>
<td>...</td>
<td>30 ...</td>
</tr>
</tbody>
</table>

2 It is known that atmospheric pressure at the surface of the earth is equal to the weight of a column of mercury 76 cm. high (Torricelli) or 1.033 grm. per square centimetre. By replacing the mercury — which is very heavy — by water, the height of the column will be 10.33 metres.
Within the caissons a pressure of 3\frac{1}{2} atmospheres is rarely exceeded.

The quality of air in the working chamber is naturally of first-rate importance for the health of the workers and their efficiency. When it be taken into account that, in addition to accelerated respiratory exchange due to trying work, the air may be contaminated by decomposition products of lubricating oils from the machines or by disagreeable or poisonous emanations of gas (carbon monoxide, carbonic acid, etc.) from the soil, the importance of carefully examining and purifying the air of the caisson will be fully recognised. Further, in estimating the carbon dioxide contained in the air of the caisson, it is the partial pressure and not the percentage which must be taken into account because, for instance, 0.5 per cent. of carbon dioxide at a normal pressure would give under the same conditions, but at a pressure of 1 atmosphere, a partial pressure of 1 per cent. (see article "Carbon Dioxide").

The use of explosives (see that article) may also cause vitiation of the atmosphere, but it must be stated that, owing to the improved quality of modern explosives, this cause of contamination is of less import than formerly.

Whenever numerous cases of discomfort or sickness occur, the air should immediately be submitted to an analysis.

In large three-shaft caissons ventilation is provided by two shafts generally utilised for supplying air, while in a third a valve is opened to permit of the escape of vitiated air. In smaller caissons the air is usually introduced by a siphon ending in a rubber tube, while foul air escapes through a valve close to the air lock in the upper part of the shaft, in order to ensure effective ventilation (fig. 1).

Experts are not in agreement in regard to the quantity of air which should be supplied to the working chamber, for, while some authorities advise 30 cu. m. per man per hour, others demand 60 cu. m.

Whilst, however, refraining from exaggeration as to the hourly quantity of air required per worker engaged in a caisson, it is advisable to stress the point that, if the air intake is insufficient, the number of cases of sickness amongst the staff becomes very high.

It is, therefore, indispensable to provide in each installation not only a minimum air supply per person employed in a caisson, but also to ensure an adequate hourly renewal of the air. The working chamber should besides be of sufficient height to permit of a standing position.

The air renewal system should be so planned as to ensure constant supply without interruption (double series of pipes, safety valves, etc.) as well as ensuring a pure quality. With a view to this, electricity only should be used for lighting, and all adequate measures should be taken to combat by ventilation the percentage of noxious gas in the atmosphere.

The excess of compressed air passes under the edge of the caisson resting on the ground, but where the working chamber rests on a soil not permitting such escape of air, safety valves should be placed in the upper part of the shaft, permitting regulation of the pressure in such a manner as to exclude any danger of explosion of the caisson. Safety valves should likewise be provided for the air lock as well as for the upper part of the shaft. They should be so installed as to permit of instantly and automatically shutting off the air in the interior of the caisson exceeding by more than 0.5 kg. that required for the work.

**Working Hours**

The ideal length of shift for different pressures is still a debatable point and great diversity of opinion exists with regard to the best distribution of working hours, though the majority of authorities favour a reduction of hours in proportion to the increase of pressure. This view would appear to be borne out by statistical experiences recorded in recent large-scale enterprises employing sufficient numbers of workers to provide a basis for reliable statistical data (see below, Statistics).

It is noted also that the lock-tenders, timekeepers and inspectors obliged to spend but little time under compression are generally quite free from bad effects.

It is evident that the longer the shift the greater will be the degree of saturation, and in consequence the longer the period required for decompression.

That the length of the shift has a strong influence on the danger index would appear to be indicated by an Amsterdam experience, where at 1½ atmospheres the substitution of an eight-hour shift for two- to four-hour shifts raised the danger index to over two and a half times what it had previously been (1 case in 223.9 descents against 1 case in 86.2 descents), and that during a less prolonged period at the same depth with the same terrain and better workers. An eight-hour shift would, therefore, appear to be over long, even at a pressure of 1½ atmospheres. Continuous and laborious proof has been collected by Dutch doctors to demonstrate that danger exists beyond doubt for long exposure at low pressures. Long shifts have in addition an indirect influence which is prejudicial to health, viz. lowering disease resistance by over-fatigue and stress.

For the above reasons authorities have pointed to the necessity of a break in a six- to eight-hour day for upwards of 3 atmospheres to avoid overstraining the heart and muscular system, or the introduction of two- to three-hour shifts up to a pressure of 3 atmospheres.
A minor recommendation is two-hour shifts up to 4 atmospheres and one hour above that limit; while finally, for a depth of 18 metres, a day not exceeding six hours, including time spent in the descent and ascent, is prescribed.

In one large undertaking the shift system adopted was as follows (3 shifts):

1. 6 a.m. to 8.30 a.m., forty-five minutes break.
2. 9.15 a.m. to 1 p.m., one hour break.
3. 2 p.m. to 6 p.m.,

giving a working day of ten and a quarter hours for under 2 1/2 atmospheres; above 2 1/2 atmospheres these periods were decreased.

The working time-table drawn up by the American Air Workers' Union is as follows:

<table>
<thead>
<tr>
<th>Shift</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 - 3 1/2</td>
<td>Up to:</td>
</tr>
<tr>
<td>3 - 3</td>
<td>2.2</td>
</tr>
<tr>
<td>2 - 2</td>
<td>2.3</td>
</tr>
<tr>
<td>1 - 1 1/3</td>
<td>2.6</td>
</tr>
<tr>
<td>40 min. + 40 min.</td>
<td>3.0</td>
</tr>
</tbody>
</table>

The rules proposed by twenty-one engineers, contractors and doctors and submitted to the New York State Labour Commission were as follows:

<table>
<thead>
<tr>
<th>Shift</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 - 5</td>
<td>Up to:</td>
</tr>
<tr>
<td>3 - 3 mins. rest for lunch</td>
<td>2.6</td>
</tr>
<tr>
<td>3 - 3</td>
<td>2.6</td>
</tr>
</tbody>
</table>

While certain authorities have suggested two shifts of three hours each up to 3 atmospheres, others recommend the following:

<table>
<thead>
<tr>
<th>Shift</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two shifts of 3</td>
<td>Up to:</td>
</tr>
<tr>
<td>&quot;</td>
<td>2.5 atm.</td>
</tr>
</tbody>
</table>

The supporters of the opposite theory urge the continuous shift system as preferable, on the assumption that the worker is practically saturated in three hours, and that, therefore, no additional risk is involved in extending that period, whereas decompression being admittedly attended by risk, the substitution of one long shift for two or three shorter ones, thereby avoiding repeated decompression in the twenty-four hours, is regarded as an advantage. Those who advocate this system (chiefly the Austrian authorities) attribute increase in the number of cases after long shifts entirely to the fatigue factor, and maintain that no limit should be imposed on the working hours which they state cannot be scientifically limited in relation to augmentation of pressure.

Though the theory is to some extent justified by the grave risk of repeated decompression, statistical experience seems to favour the two-shift system, decreasing as pressure is augmented. A minority of experts recommend that workers should not be kept longer than four years on compressed air work, as there is likelihood of enlargement of the heart after longer periods. This view is against the opinion, however, of the majority of authorities, who are believers in the increased resistance of carefully selected workers with long experience.

### Decompression

The measure of first importance to be taken in regard to decompression is to avoid unduly rapid decompression. The longer the time spent in compressed air the greater is the amount of nitrogen dissolved in the organic liquids (up to the point of complete saturation) and in consequence the longer must be the period spent in decompression. Desaturation is, in fact, not simply a reversal of the saturation process; it is complicated by other factors which will be referred to later. While it is agreed that time spent in decompression should be included in the working hours (the only practical method of assuring the application of adequate prophylactic measures), so far no system of decompression meeting with general approval has been established. This is reflected in the various regulations issued on the subject, which show great divergence in regard to the period allowed for decompression.

Uniform decompression (decompression at a uniform rate of progress) is the oldest and, until recently, almost universally practised system. Earlier regulations demanded one minute for 0.1 atmosphere pressure drop, but cases of sickness and even death often occurred with this system which was later extended to one and a half minutes (Siberstern) and two minutes per 0.1 atmosphere (with pressure not exceeding 2 atmospheres).

The English experts, Hill and Greenwood, after subjecting to pressures of 5.3 and 6.4 atmospheres respectively, decompressed at 2.2 minutes per tenth of an atmosphere and only experienced slight transient symptoms, while 2.3 minutes per 0.1 atmosphere was found by them to give fairly good, if not very satisfactory, results.

The Committee appointed by the First Congress on Occupational Diseases (Milan, 1906), including Drs. Gilbert (Belgium), Langlois (France), Gigholi
Decompression without doubt represents the most dangerous time spent on compressed air work, and without desiring to enter into the less debatable questions regarding the physiological condition of the worker, compression, ventilation, working hours, etc., the Committee nevertheless considers it its duty to emphasise as the essential problem: conditions of decompression.

Scientific calculations, experimental data and the results of practical observation all lead to the conclusion that, in order to avoid as far as possible the formation of gas bubbles, decompression ought to take place at most at one-tenth of an atmosphere per minute. In work carried out at a pressure of 14 atmospheres and over, a heated rest room and a recompression chamber provided with oxygen apparatus should be demanded. These precautions are indispensable, because even with decompression of one-tenth of an atmosphere per minute, the formation of gas emboli is still possible.

Other methods of decompression, such as the following, have been proposed:

<table>
<thead>
<tr>
<th>Atmospheres</th>
<th>Shift</th>
<th>Decompression</th>
</tr>
</thead>
<tbody>
<tr>
<td>+2</td>
<td>6 hrs.</td>
<td>30 mins.-1 h.</td>
</tr>
<tr>
<td>+3</td>
<td>4 hrs.</td>
<td>1-2 hrs.</td>
</tr>
<tr>
<td>+3</td>
<td>2 hrs.</td>
<td>2 hrs.</td>
</tr>
</tbody>
</table>

Decompression at uniform progress was condemned by Haldane primarily because it makes no use of the possibility of utilising the greatest permissible nitrogen extracting stress; secondly, because to be quite safe uniform decompression is so slow that it becomes irrational and unpractical and however slow it may be, the difference in partial pressure between the N dissolved in the tissues and the external air goes on increasing during compression; thirdly, following short exposure it merely prolongs exposure to effective pressure.

The black lines in the graph shown in the next column indicate the changes in pressure; the fine lines represent the curves of saturation and desaturation by nitrogen of parts of the body which attain in five, ten, twenty, forty, and seventy-five minutes the half of the nitrogen saturation.

Decompression time during the first half of the time is wasted and, since it is not the absolute pressure of N in the tissues, but the relative difference existing between it and the outer atmospheric pressure that matters, the tension differences augment towards the end and danger is at its maximum at the end of the operation.

Note. — The diver descends to the bottom (51 metres) and remains there fourteen minutes. He returns to the surface forty-six minutes after his descent.

In recommending the system of "stage decompression" (see article "Divers"), Haldane based his argument on the fact that it is possible to decompress rapidly and without danger from 2 atmospheres (absolute) to normal pressure, and that it is possible to diminish the pressure with equal safety from 4 to 2 or 6 to 3, the danger of rapid decompression depending not on the absolute difference between initial and final pressure but on the relation existing between these two pressures. While this proportion is only of the order of 2 or 2.3 to 1, sudden decompression is without danger. It becomes dangerous when the proportion is 3 or 4 to 1.

Haldane expresses his view as follows:

The principle of this method is that the diver or worker in compressed air is brought rapidly to half the absolute pressure (or a little further if his tissues are not saturated), stopped there for a time, then decompressed a little further, after sufficient time has elapsed to allow the maximum nitrogen pressure in any part of his body to become not more than twice the nitrogen pressure of the air at the lower stage. He is then brought on by further stages on the same principle until he reaches atmospheric pressure.

While this method is greatly superior to the former method of slow and uniform decompression, it does not itself suffice to exclude accidents, at least slight accidents, serious and fatal...
accidents being, however, eliminated (see article "Divers"). [Opinion of partisans of the system; for contrary view, see following page.] Haldane recommends also the provision of a room or "purgatorial chamber" or lock at half working pressure with two locks on either side — one opening into the working chamber and the other giving access to the outside air. It has been suggested that in such a lock workers could change their clothes and even have meals in order to effect a saving of time.

A combination of uniform and stage decompression had been proposed by Catsaras in 1889 with a view to avoiding accidents occurring to divers. He says:

It is essential to decompress slowly and by several stages (at a rate of thirty seconds for each 5 ft. with a halt of one minute at each 10 ft. of depth). In this way the slow rate ensures a minimum quantity of gas being liberated, while the fact that the worker is regularly subjected to a recompression of one minute serves to redissolve the amount of gas liberated by slow decompression for two fathoms (French fathoms or brasses = 5 ft. 3.771 in.).

The difference between the method of Catsaras and that of Haldane, which has for long been applied with successful results in the English Navy and in Germany, is that Haldane advises the substitution of decompression in successive stages for decompression at slow and uniform rate, while Catsaras considers as more effective a combination of the two systems, that is to say, slow decompression arrested for short intervals.

Experiments with goats showed the sickness rate to be five times as great with uniform decompression as with stage decompression.

Experiments engaged in by Bornstein during the construction of the Elbe river tunnel (at 2.8 atmospheres) revealed that the morbidity rate for the shift subjected to uniform decompression was 1.05, while that for the shift subjected to stage decompression only reached 0.82, but Bornstein admits that the results were not as favourable as those which might have been theoretically expected. One serious disadvantage of the method of stage decompression recommended by Haldane is that much mist is formed in the air lock by the rapid pressure drop which causes a considerable fall in temperature. In consequence the workers are exposed to great risk of becoming chilled and the peripheral vessels contract, and this is apt to decrease the liberation of N from organs fed by these vessels.

It would be possible to meet these disadvantages and risks by mechanical drying of the atmosphere (which has

<table>
<thead>
<tr>
<th>Working pressure per sq. inch</th>
<th>After 3 hours' exposure</th>
<th>After second or third 3 hours' exposure</th>
<th>After 6 hr. or longer of continuous exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>lb.</td>
<td>Minutes</td>
<td>Minutes</td>
<td>Minutes</td>
</tr>
<tr>
<td>18-20</td>
<td>2</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>21-24</td>
<td>3</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>25-30</td>
<td>5</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>30-34</td>
<td>6</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>35-39</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>40-45</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>
not, however, been tried yet) or by physical exercises. Some authorities are not in favour of the latter method because of the additional fatigue which it may involve. Haldane, on the other hand, has shown that muscular exercise by considerably stimulating circulation favours elimination of the nitrogen.

Workers should, therefore, be provided with means for keeping warm (blankets, hot drinks) not only on leaving the air lock, but during the whole period of decompression — the moment at which chills are most to be feared. Facilities should be provided for drying working clothes in a heated room. In the German Navy baskets of coke are suspended round the lock in winter with a view to heating the air therein.

The English system was described by Dr. Gilbert (in 1912) as likely to create a favourable impression at first view, though encountering serious obstacles on reflection. It involves in fact very risky moments — those of successive instantaneous halts — and is based on the affirmation that danger is reduced to zero when the maximum pressure has not exceeded 1-1.3 gauge pressure.

The proportion suggested by Haldane, 2.3:1, cannot be accepted without reserve, since a certain number of accidents, some of which were fatal, in Belgium and in Germany have drawn attention to defects in this system and to the need for modifying it. The complexity of the human organism comprises parts of very varying density with a very different power of absorption and furnished with defensive mechanism, the sudden coming into play of which may considerably disturb the expected development of desaturation.

The exigencies of industrial work exclude the possibility of retarding the process of decompression to the point of permitting of discharge of gas from the organism without difficulty. It is therefore essential to find out how to make the best use of the maximum time compatible with the organisation of the work which can be accorded to the workers for decompression.

Gilbert has sought by his system to avoid any method likely to interfere with the regular and successive progress of desaturation, with a view to preventing the bringing into play of organic reactions and more particularly derangement of vasomotor control, which may have the effect of isolating, sometimes for quite a long period of time, a whole organ. It must be recalled here that the irrigation of the organs of the body does not proceed in a homogeneous manner, that the tissues have not the same absorption coefficient for gas, and that the viscosity of the body fluids is also very variable. What is important, then, is to render as far as possible uniform the organic desaturation. It is therefore preferable to get back to progressive decompression at a decreasing speed with breaks, for two reasons:

1. Given an equal volume, the weight of gas eliminated is more considerable according to the strength of the pressure;
2. The risk of chills to the organism increases with increased time spent in the air lock.

This system permits of a halt at the least alarm and is better adapted to rapid recompression in the event of such being advisable. The intervals should occur before the point at which, theoretically, risk of effervescence represented by the proportion $\frac{1}{10}$ of organic saturation to the pressure obtaining in the surrounding air occurs. Time-tables for decompression should take account of the length of time spent by the worker under compression, and in this way it would be possible to maintain during decompression relative correspondence between the tension of gas in the air lock and the discharge of gas from the organism.

A comparative instance illustrating three methods, calculated in accordance with the time prescribed by Dutch law, demonstrates better these advantages:

### Decompression from 5 Atmospheres Absolute Pressure to 1 Absolute in Eighty Minutes

(R = relation of the organic saturation to the pressure of the surrounding atmosphere)

<table>
<thead>
<tr>
<th>Methods</th>
<th>At the end of 30 min.</th>
<th>At the end of 50 min.</th>
<th>At the end of 60 min.</th>
<th>At the end of 80 min. (exit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular decompression</td>
<td>R 1.20 to 1</td>
<td>1.33 to 1</td>
<td>1.43 to 1</td>
<td>1.88 to 1</td>
</tr>
<tr>
<td>Dutch law</td>
<td>R 1.11 to 1</td>
<td>1.35 to 1</td>
<td>1.32 to 1</td>
<td>2.01 to 1</td>
</tr>
<tr>
<td>&quot; Broken &quot; decompression</td>
<td>R 1.34 to 1</td>
<td>1.50 to 1</td>
<td>1.45 to 1</td>
<td>1.55 to 1</td>
</tr>
</tbody>
</table>
In conclusion, a system which may be regarded as a modification of Haldane's method was followed in the construction of the East River tunnel by H. Japp. Whereas by Haldane's method decompression would have taken ninety minutes as work had been carried on for several hours at a pressure of 40 lbs., under the system adopted decompression was accomplished in forty-eight minutes. The tunnel was in three sections, the pressure in these being 40 lbs., 29 lbs., and 12½ lbs. respectively and halts of five minutes, eight minutes, and fifteen minutes were made in each of these successively with a walk of 1,000 ft. between each, giving an additional ten minutes between the first two stages and thus bringing the total decompression time to forty-eight minutes. The air saturation of workers on quitting the lock was 27 lbs., and the author of the passage concludes from the experience that it is practically safe to decompress rapidly from pressure of 27 lbs. He has drawn up a decompression table based on this experience that the outer air flattens the caisson.

The *specific risks* to which the caisson workers are exposed are represented by pathological disturbances noted during compression and decompression or after long periods of work.

Variations in atmospheric pressure exert a marked influence (certain authorities, however, consider, on the other hand, that the influence in question is extremely slight) on the exchanges of the human organism. Yet the superoxygenated state of the atmosphere in the case of increase of pressure increases but slightly the respiratory exchanges and the oxygen content of the blood. It must also be stated that in caisson work the high tensions at which oxygen exerts toxic effect are never attained.

Individuals subjected to the action of compressed air observe an increased sensation of heat in the surrounding atmosphere (the air being heated by the compressor), a feeling of well-being with increase of energy and of appetite. The number of heart beats and the arterial tension diminish while there is an increase in the speed of inspiration. The peripheral stimulation, at the beginning especially, is retarded and the blood thrust back towards the internal organs stimulate organic combustion there (Gilbert).

These salutary effects, however, become quickly effaced and — according to certain authorities — signs of wilting and depression of all the faculties become noticeable. It should be remarked in passing that there appears to exist amongst many individuals a quite particular aptitude for work in compressed air.

Already at a pressure of 1 atmosphere the voice becomes nasal and whistling impossible; there is difficulty in hearing, whilst the mucous membranes at times seem dry and there is not infrequently obstruction in the nasal passages. The whistling sound of compressed air entering the air lock with sudden force is at times excessively disagreeable. The high
temperature of the surrounding atmosphere causes free perspiration on the least muscular effort.

Fatigue during work in the caisson is subject to the same general laws as ordinary fatigue but heavy muscular work is less fatiguing.

When compression is too sudden or too intense or when decompression is effected too rapidly, the worker is exposed to injuries which may be very serious and even terminate fatally.

Trigger records meeting in the course of his experiments in caisson work, with the occurrence of pains in the limbs of workers, but the earliest scientific investigations engaged in in a consecutive manner were those of Pol and Watelle (1854), who put forward the subsequently discredited mechanical pressure theory. As will be mentioned later, the correct theory was first expounded by Hoppe-Seyler in 1857 and confirmed and proved conclusively by animal experiment in 1878 by Paul Bert, to whom also is due the credit for the first attempt at effective prevention. A whole series of experts in the different countries have subsequently contributed to the study of the disease. The names of a few of these only may be referred to: Layet and Langlois, Von Schroetter and Silberstern, Catsaras, Hill, Haldane, Damant, Gilbert, etc.

During compression the phenomena referred to above may occur with severity varying in accordance with the individuals concerned and in accordance with any affections to which they are liable (catarrh of the respiratory passages, dental caries, digestive derangements, over-eating, etc.). During this first phase the following symptoms may be met with: hemorrhage of the nasal or buccal mucous membrane, rupture of the ear trumpet, etc. Certain subjects suffer from neuralgia, alteration of the senses of hearing, touch, taste, and smell. Such phenomena are very frequent in beginners and fairly rare amongst healthy workers already accustomed to work in compressed air.

In conclusion, it may be said that during the phase of compression there exist merely slight risks for normal workers, the most outstanding of which are derangements of hearing due to the difference of pressure existing on the two surfaces of the ear drum and to the reflux of mucous secretions in the Eustachian tube.

The most serious accidents known under the name of compressed air illness or caisson disease do not as a rule occur until decompression takes place, so that the workers are wont to say, "You pay on going out". The appearance of such phenomena is mostly preceded by a period of latency which varies, according to certain authorities, from a quarter-of-an-hour to several hours. One expert, on the contrary, holds that fairly frequently symptoms only appear three to twelve hours after the worker has quitted his work. However that may be, it is established beyond doubt that in several cases the worker has been attacked on the way home, or even after arrival at his home, by paraplegic phenomena at a time when it would have been thought that he was already free from any danger.

It must also be stated that individual susceptibility plays a part which so far has not been accurately determined. The rapidity of desaturation of the tissues depends chiefly on the biochemical activity of the tissues themselves and effective action of the respiratory and circulatory systems. That individual difference in these respects exists has been proved by practical experience as well as by laboratory research. Age and habits also exert an important influence in the matter. In seeking the explanation of certain phenomena difficult to explain, recourse has often been had to the influence of endocrine secretions due to certain tacked on states. It has, for instance, been stated that a worker in perfect health may work for a long time under strong pressure without showing any symptoms during decompression, while he may, on the other hand, suddenly be attacked at feeble pressure. Individual differences are however even more remarkable in regard to the duration of the latency period and the nature and gravity of symptoms amongst workers subjected to the same conditions. So far there has not been noted varying degrees of resistance between different races. In fact during the construction of the bridge over the Blue Nile, it was remarked that the Sudanese and the Egyptians withstood the work just as well and even better than Europeans.

Accidents due to compressed air may be peripheral or central in origin.

**Symptoms of Peripheral Origin**

In slight cases the worker is affected with a sensation of slight heat, which passes off easily. This sensation then becomes very intense and the worker perspires freely. In more serious cases
the worker experiences a sensation of dry irritating heat with sweating, distressing pruritus, and an intolerable burning sensation which makes him scratch himself furiously. This phenomenon, which workers call "fleas," is continuous after subjection to strong pressure and usually disappears after abundant perspiration. The hypothesis that such irritation is specially likely to appear where perspiration is obstructed by bubbles of air formed in the excretory channels of the sweat glands has been contested by many authorities. The muscles and joints are the seat of more or less violent pains, designated by the workers as "bends," "screws" or "staggers" (in French, *moutons*) accompanied by painful swelling in the sinew reflexes. These bends are localised chiefly in the elbow, the shoulder, and the calf of the leg.

Labyrinthine troubles, sometimes in the form of Menière’s disease (*vertige de Menière*), are slow in disappearing. In this group may also be classed phenomena such as dyspnoea, distress, nausea, etc.

As affecting the circulatory system there have been reported serious cases with bluish pigmentation of the chest and abdomen (emboli of the superficial veins), localised edema, and prostration due to collection of gas bubbles in the right ventricle.

Besides dyspnoea there have been reported attacks of asthma, spitting of blood, and more or less diffused emphysema. There has also been noted in one case necrosis of the femur due perhaps to thrombosis of the medullary artery.

The eye may be the seat of lesions resulting in diplopia, nystagmus, refraction of the field of vision, transient or even permanent blindness, sometimes without any important ophthalmoscopic sign, and even in bilateral optic neuritis with oedema of the macula, etc. (Pick, Oblath, Oliver, etc.). A singular case was studied by Harlon affecting a worker who suffered from serious ulcerous keratitis with hypopion as the result of a trigeminal lesion.

The phenomena in question are generally caused by change in the volume of gas in certain cavities of the organism (middle ear, digestive tube, etc.) or by liberation of gases dissolved in the organic fluids and their expansion within the tissues.

Accidents of the Central Nervous System

These are without doubt the most serious consequences. They may have their origin in the brain, the medulla oblongata or in the spinal cord.

The development and issue of these lesions is naturally closely connected with the character of the fundamental lesion (organic or functional) arising in this case also from obstruction of the capillary vessels (emboli) or due to gaseous extravasations. The illness will be temporary or permanent according as to whether the circulation at the seat of the emboli resumes more or less rapidly its normal course.

In slight cases there are phenomena of congestion characterised by headache, vertigo, convulsions, nystagmus, vomiting, etc. Clinical pictures of cerebral or pulmonary apoplexy and of paralysis or paraplegia due to cerebral ischaemia, have also been met with. It is possible to group these central lesions as follows (according to Layet):

1. **Cerebral affections.** — (a) auricular form, frequent but transitory; this form is more serious and more frequently met with amongst divers;

   (b) vertiginous form with or without complications affecting the ears;

   (c) form involving syncope noted amongst divers;

   (d) hemiplegic form, very rare, accompanied by monoplegia or hemiplegia, etc.;

   (e) form involving asaphasia: at the beginning and as a transitory symptom there is noted stuttering and a certain difficulty in articulating; amongst divers, however, complete asaphasia is met with;

   (f) death by cerebral apoplexy (chiefly amongst divers).

2. **Bulbar affections.** — Pulmonary form characterised by arrest of the respiratory function or the cardiac form is known under this heading. Death in the first case occurs due to pulmonary apoplexy and in the second to syncope. Generally the cases in question are very serious with fatal termination.

3. **Medullary or spinal affections.** — These are without doubt the most frequent. They are characterised by suppression or perversion of sensibility and motility. The victim is attacked with paraplegia or monoplegia with or without loss of bladder and rectal control, painful anesthesia and heaviness of the lower limbs, etc.

Recovery follows as a rule; but where the marrow is affected by serious
haemorrhage, myelitis with all its serious consequences may supervene.

Authorities are not in agreement as to whether caisson disease may or may not cause permanent lesions. While certain experts affirm that medical literature does not record any case of organic lesions as the result of compressed air (the cases of anaemia being possibly brought about by bad objective conditions), other available statistics would appear to prove the permanence of the injuries caused.

An American enquiry affecting a large number of workers who had left work many years previously, revealed derangement of hearing amongst up to 7 per cent. of the workers examined, paresis of the lower limbs amongst 21 per cent., and of the upper and lower limbs amongst 3.7 per cent. and chronic pains and a certain stiffness of the limbs amongst 6 per cent. One worker was found to have symptoms of caisson workers' myelitis, and several others were affected with symptoms which seemed to indicate the presence of osteo-arthritis of the vertebral column. Another enquiry, affecting 671 workers carefully examined on entering the occupation in question, revealed that 5 workers showed signs of pulmonary tuberculosis at the end of one year's work in compressed air.

The same American investigation proved that the application of rigorous measures of prophylaxis and of recompression had the effect of diminishing considerably the number of cases of permanent invalidity. Whilst the preceding statistics had shown a percentage of about 10, the measures thereat applied resulted in the reduction of this figure to 1.3 per cent., of which 0.3 per cent. only were cases of paralysis.

The specific symptoms affecting caisson workers have been explained by scientists by different theories which are deserving of detailed analysis.

The exhaustion theory imputing effects to the result of exposure, to cold (dampness) and fatigue gives an inadequate explanation and only merits consideration in so far as these causes act as minor contributory factors.

Carbon dioxide poisoning has also been suggested, but it does not explain the presence of bubbles in the blood revealed on post-mortem examination. On the other hand, were this the reason, the morbid effects would appear during exposure to pressure which is never the case (see also article "Carbon Dioxide").

It has likewise been supposed that the cause of the disease should be sought in the exposure to high tension oxygen, since this gas breathed under increased pressure rapidly produces toxaemia and has been proved by animal experiment (P. Bert) to arrest tissue metabolism.

In compressed air there is indeed increase in the partial oxygen tension, but, on the one hand, excess oxygen in the surrounding air augments only to a very slight extent the quantity of oxygen present in the blood and, on the other hand, the high tensions at which oxygen exerts a toxic action are not attained in caissons. Animal experiment with oxygen and compressed air at equal pressure showed that with the former there were toxic effects already during compression and with the latter not until decompression.

Further theories to be considered are: the theory of alteration of gases, and finally the two most important theories: the mechanical theory and the pneumatic theory. Neither the alteration of gases by chemical combination with the blood nor the theory of congestion of blood vessels and organs as the result of mechanical pressure provides, however, satisfactory explanation of the illness. According to the mechanical theory (sometimes also referred to as the hydraulic theory), the illness is assumed to be due to the following causes: blood being driven by compressed air from the peripheral parts of the body into the internal organs; a congested state of the capillaries of the nervous system; distension of the blood vessels which does not recover elasticity quickly enough on removal of compression; and finally, the sudden afflux of blood to periphery on decompression with sudden diminution of circulation in central parts of the body, the localised pain being believed to be of a rheumatic nature as a result of exposure to cold and moisture.

The gas bubble or pneumatic theory or theory of augmentation and liberation of gas in the blood and the tissues, sustained and demonstrated by P. Bert, has been incontrovertibly confirmed microscopically and by post-mortem findings. At the present time it is possible to affirm that the effects of compressed air manifested during decompression are often the result of the presence of bubbles of free N in the organism. This affirmation has a solid foundation. It is suggested that it may be an acid, and further is merely in the nature of very plausible hypothesis without scientific confirmation.

Normally the blood contains oxygen carbon dioxide, a little nitrogen and traces of argon (0.04 per cent. per litre).
The proportion of the gases is as follows:

<table>
<thead>
<tr>
<th></th>
<th>arterial blood</th>
<th>venous blood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>c.c.</td>
<td>c.c.</td>
</tr>
<tr>
<td>0.0</td>
<td>19.0</td>
<td>11.0</td>
</tr>
<tr>
<td>20.0</td>
<td>39.0</td>
<td>23.4</td>
</tr>
<tr>
<td>1.8</td>
<td>19.8</td>
<td>11.0</td>
</tr>
<tr>
<td>50.8</td>
<td>58.8</td>
<td>39.0</td>
</tr>
</tbody>
</table>

The proportion of air is simply dissolved in the plasma, and it is a well-known fact that its quantity augments with the pressure of the air. As the result of a series of experiments, P. Bert found that the blood of animals subjected to progressively increasing pressures showed the following values:

<table>
<thead>
<tr>
<th>Pressure (in atmospheres)</th>
<th>c.c. of oxygen contained in 100 c.c. of blood</th>
<th>c.c. of N contained in 100 c.c. of blood</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20.0</td>
<td>2.2</td>
</tr>
<tr>
<td>2</td>
<td>20.0</td>
<td>3.0</td>
</tr>
<tr>
<td>3</td>
<td>21.6</td>
<td>3.9</td>
</tr>
<tr>
<td>4</td>
<td>22.7</td>
<td>6.0</td>
</tr>
<tr>
<td>5</td>
<td>23.1</td>
<td>7.0</td>
</tr>
<tr>
<td>6</td>
<td>23.4</td>
<td>9.4</td>
</tr>
</tbody>
</table>

By repeating this experiment in vitro P. Bert found perceptibly higher values, since in a living organism the blood has no time during its passage through the lungs to fix all the oxygen which theoretically it would be capable of dissolving.

It has been stated that muscular work increases the rapidity of saturation and that, on the other hand, absorption of the gases, especially of N, by fatty substances occurs to a greater extent than the laws above referred to would induce one to believe.

If account be taken of the fact that in those parts of the organism where fatty tissue is more abundant the circulation of the blood is less developed and occurs more slowly, it will be easier to understand why the morbid phenomena caused by compressed air are likely to affect certain centres of the organism rather than others.

During decompression there occurs in the blood a phenomenon which is the inverse of those just described. The blood gives off the quantity of gas which it has absorbed under compression and the quantity of gas liberated is the greater the more pronounced the difference in pressure. This desaturation takes place in the form of bubbles, and while oxygen bubbles are less dangerous (since they can be fixed by the tissues), those of N, which are in the form of extremely small bubbles, are very slowly reabsorbed and arrive in the capillaries where they produce emboli.

Lungs have been estimated to give off 1.55 c.c. of N per minute, but since for instance, supposing the entire human body to be possessed of the same absorption capacity as the blood, an individual weighing 70 kg. may have in solution at 4 atmospheres plus pressure about 3.360 c.c. of N, elimination by the lungs during decompression is too slow to avert bubble formation. In the blood vessels of the super-saturated tissues the bubbles of N at the moment of rapid decompression are liberated in a violent fashion, similar to the manner in which carbon dioxide escapes from a bottle of mineral water opened suddenly. This violent liberation of N usually overcomes the resistance offered by the walls of the vessels (especially the capillaries) and causes more or less serious haemorrhage according to the violence of the desaturation, etc. The fatty tissues act, as has been said, as a reservoir for N, and just as they reach saturation more slowly and hence become more easily the seat of lesions. In fact, whilst gas emboli may still be found in the veins at the end of forty-eight hours, in a tissue such as the spinal marrow they may remain for several days without becoming dissolved. It is for this reason that lesions are found to be frequently located in the lower part of the spinal marrow or at the level of the joints or in the subcutaneous tissue.
etc., since fatty substances are more abundant at these points and the circulation of the blood therefore slower.

The physical laws in relation to the capacity for compression of gases state that the space occupied by a gas is in inverse proportion to the pressure, and it may hence be affirmed that the risk of effervescence is similar for sudden changes from 6 to 3 atmospheres, from 4 to 2 atmospheres, and from 2 to 1 atmosphere. While accidents are rare or almost unheard of at a gauge pressure not exceeding 1.3 atmospheres, that is to say, when the proportion of organic saturation to the atmospheric pressure remains within the limits of 2.3 to 1, there is no danger in passing rapidly from 6 to 3 atmospheres or from 4 to 2 atmospheres, provided that the organism is allowed time to regain its equilibrium between the ascents.

A comparison of the two systems in question (uniform and stage decompression) reveals the fact that the progress of desaturation would appear to be effected theoretically more effectively by following the English method. If, in fact, it is desired to decompress, for instance, in thirty-two minutes from a pressure of 5 atmospheres absolute pressure, at the end of the time the proportion between the saturation and the pressure, when following the English method, is 2.49 and in the other 2.93 to 1. One fact is revealed by consideration of these circumstances, and that is that, even with ideally favourable conditions, it is impossible to drop with safety in half-an-hour from 5 atmospheres absolute pressure to ordinary barometric pressure.

In the case of regularly decreasing decompression, the divergence between the pressure of the airlock and the tension in the tissues would augment progressively. In fact, while admitting that gradual decompression after complete saturation may be attained in ten minutes, the tension drop would be attained in such a manner that, at the moment at which the extraordinary tension had been completely reduced, the human organism would still retain an excess of over 76 per cent. This method is therefore hardly advisable for rapid elimination of the excess N.

What is, however, of primary importance is the exact determination of the risk of formation of bubbles of free gas in the blood at any given moment. From this point of view, the comparison between the two systems proves that, while the risk is considerable at the beginning of the instantaneous drop (first five minutes), it follows thereafter a gradually diminishing progress. In uniform decompression, on the other hand, it is exactly the contrary which takes place.

The advantages of the instantaneous drop must, therefore, be sought within the limits which exclude all possibility of effusescence. This critical point can be none other than the requisite difference for avoiding the formation of gaseous bubbles in the organism. It is not, however, possible to arrive at a mathematical estimation of this point; and it is therefore necessary to base estimation thereof on the facts of past experience.

Experience and practice have proved that frequent and serious accidents of decompression as the result of high pressure are proportionally less numerous at average pressures and still more rare at slight pressures. Certain authorities admit even that up to an absolute pressure of 2 to 2.3 atmospheres there is no danger even from instantaneous decompression for the human organism in the case of a normal individual.

The decompression method invented by Haldane is based on this hypothesis. When the excess of gas in the organic fluids or tissues is violently released there may occur accidents either slight or serious according to the localisation and the quantity of the bubbles liberated.

The laws of Mariotte, Dalton and others relative to the absorption of gas by liquids, the volume of gases under pressure and their partial tensions, etc., are equally applicable to gases present in the blood in the lymphatic and cerebro spinal fluids, etc., in activity in the organism as in the gases contained in solutions prepared in laboratories (Gilbert):

1. The human organism taken all over may attain roughly the same degree of saturation by gas as that attained by the blood.

2. The mass of blood in circulation represents about one-twentieth of the entire body weight (Haldane).

3. The entire amount of blood in circulation traverses the lungs in approximately one minute (Haldane) if the subject is at rest and in good health. This space of time suffices, therefore, to saturate the blood with the gas contained in the pulmonary alveoli.

4. Let it be supposed that the blood is uniformly diffused throughout all parts of the body and that, these being homogeneous, absorb equal quantities of gas.
The progress of saturation during the first ten minutes would then allow of the calculation that the excess gas in the tissues, as a percentage of the total saturation, after the tenth minute is 8.1 per cent., and that roughly 50 per cent. of the excess will be attained in fifteen minutes and 75 per cent. in thirty minutes and finally, 94 per cent. in one hour.

If the progress of desaturation with an instantaneous drop is studied, even on the above favourable hypothesis of a homogeneous distribution of N throughout the organism, the latter will at the end of ten minutes' decompression still retain more than 50 per cent. of the gas, whatever may have been the pressure encountered.

STATISTICS

It is extremely difficult to isolate and appreciate exactly the various contributory causes which serve to augment morbidity and mortality rates from caisson disease, but repeated observation and study have proved the adverse influence exercised not only by unduly rapid decompression, which is, of course, the principal cause, but also by long exposure and heavy work involving strain and fatigue under compression.

Silverstern estimates that each worker suffers at least twice a year from the effects of decompression, recompression applied immediately after the accident serving to eliminate all symptoms in the majority of cases. The same authority made a study of 190 cases, 94 of which suffered from muscular and articular affections (all of which recovered); 35 cases of spinal cord paralysis and angio-paralytic troubles (24 recoveries, 1 being permanently crippled); 17 cases of Ménières syndrome (12 recoveries and 5 cases of complete disablement); 5 cases of various central affections (4 recoveries and one total incapacity); 12 cases of asphyxia (10 recoveries, 2 deaths); 27 cases of affections of the ear drum or middle ear (26 recoveries and 1 partial incapacity).

Amongst derangements of hearing reported there were 11 cases of hyperemia of the ear drum, 12 haemorrhages into the tympanum, 3 cases of myringitis, and 1 case of supplicative otitis media.

Amongst 1,361 decompressions on a tunnel construction, there were 680 cases, of which 624, or 91.8 per cent. were merely localised pains; 4, or 0.6 per cent., cases of vertigo; 11, or 1.6 per cent., cases affecting the central nervous system, and 1 case of dyspnoea (0.14 per cent.). In the 624 cases of localised pain, 335, or 49.3 per cent., involved the central nervous system and musculo-skeletal system. Of the 11 cases affecting the central nervous system, 8 were considered sufficient to supply reliable data. Other statistical data assembled during the construction of the

 jury to the spinal cord. The case of dyspnoea, or "chokes", was the result of careless decompression. Before precautionary measures were adopted, death on exit from the caisson was not an uncommon occurrence. One authority relates that an English company lost from 10 to 24 men in one year. In the building of the first Hudson tunnel there were 10 deaths in one year amongst 45 to 50 men employed at the work, or 25 per cent. mortality, which was reduced to 1 per cent. after the installation of a medical air lock constructed on modern lines. In several more recent large-scale undertakings with up-to-date preventive measures, no fatalities have occurred. Mortality statistics expressed as a percentage of decompression cases provide the following data:

<table>
<thead>
<tr>
<th>Number of Decompressions</th>
<th>Number of Deaths</th>
<th>Per cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>British Admiralty</td>
<td>680,000</td>
<td>4</td>
</tr>
<tr>
<td>East River Tunnels (United States)</td>
<td>550,000</td>
<td>20</td>
</tr>
</tbody>
</table>

During construction of the Elbe Tunnel there were 165 cases in the first six weeks owing to unduly short time being allowed for decompression. Later, with extension of decompression times, 17 cases occurred in eight weeks. With still longer time for decompression, the number of cases diminished further, but the percentage for the night shift always persisted that for the day shift by about 50 per cent.

The following figures relating to a recent American enterprise, where the pressure varied between atmospheric pressure and a pressure of 2.5 atmospheres, show the incidence rates in relation to pressures and hours of labour.

Amongst 188,496 decompressions for workers employed in the caissons during eight hours at a pressure below 15 lbs., (gauge) there was not one single case of disease, but in 61,342 decompressions after compression of from 15-21 lbs. there were 16 cases, all however of a trivial nature. After a gauge pressure of from 22 to 30 lbs., with double three-hour shifts separated by three hours' rest, the number rose rapidly from 3 at 23 lbs. (24,018 decompressions) to 139 at 29 lbs. (56,092 decompressions) for a total of 320,681 decompressions.

The time spent on decompression remaining relatively the same, the cases became much less frequent, in spite of the increased pressure, after reduction of the shift.

From 30-35 lbs. there was a gradual rise in the number of cases, giving a total of 250 cases for 205,145 decompressions. At a pressure of 34-40 lbs., 165 cases occurred in two one and a half hour shifts with a three-hour interval and, here again, fewer cases occurred as a result of the reduced shift. Two hours at 34 lbs. being shown to be too much, the change required to be made at 34 lbs., rather than at 35 lbs. Above 36 lbs., the decompressions were not considered sufficiently numerous to supply reliable data. Other statistical data assembled during the construction of the
tunnel under the Hudson River, where the maximum pressure attained was +35 lbs., treat of accidents in relation to the moment of their occurrence after decompression. Of 1,419 cases reported affecting 3,500 workers, 43 per cent. occurred within half an hour of leaving the caisson, and 50 per cent. from a half to one hour after decompression, or 75 per cent. within the first hour. Another analysis gave 50 per cent. of cases within thirty minutes following exit from the caisson, and 95 per cent. within three hours. Of the remaining 5 per cent., 1 occurred six hours after exit and 4 were reported as occurring from fifteen to twenty-three hours after decompression.

In one of the East River tunnels, out of 436 cases 64.2 occurred in the first hour, 77 or 17.7 per cent. in the second hour, 30 or 6.9 per cent. in the third hour, and 14 or 3.2 per cent. between the fourth and the eighteenth hour; while for another tunnel, where a larger number of workers was employed, there were 85.9 cases during the first hour.

Future investigation and study of the problem should proceed along the lines of establishing carefully collected and accurate comparative statistics, taking account, not as at present the case, of certain factors or all factors of influencing the case rate, for instance: conditions of entry to work, total working days and distribution of shifts, the total number of working shifts, strength, duration and frequency of single shifts, length of intervening rest periods, manner and time of compression and decompression, physical and chemical properties of the air in caissons and variations of these, maximum pressure, number of cases, number of shifts affected, age of workers affected, numbers of symptoms, and respite from symptoms, and all precautions taken, conditions of recompression and other treatment, age, constitution, housing, and habits (alcohol) of workers, sickness other than caisson sickness, meteorological and climatic data, nature of terrain, running or still water, presence or absence of gas, etc. There is suggested for a uniform method of observation because of the immense importance of statistical data as an indication of the precautions which ought to be adopted. It has been suggested that a "danger index" should be established showing sickness incidence for a specified number of shifts, and that there should also be a numerical computation of severity of cases, attempts being made thereupon to keep both indices somewhere near a reasonable average by means of good medical supervision.

**First Aid**

Recompression was first practised by workers themselves as a natural relief from symptoms, and its efficacy has been established by animal experiment and by practical experience, which have shown it to be the only possible treatment for curing muscular pains and symptoms which persist after leaving the air lock. Recompression, however, ought to be applied immediately, though it has been known to succeed even after lapse of eight to twelve hours, though in the latter cases the results can never be quite so successful.

One American company provides all workers with badges to be worn at all times showing location of medical locks, and the ambulance service has instructions to rush all cases occurring throughout the city not to hospital but to the nearest lock.

Where work is carried out at considerable depths, workers should live as near as possible to the works to facilitate speedy recompression treatment where necessary. Some authorities even urge the necessity of a hostel for workers beside the works for this reason. Various methods of recompression have been recommended. Most authorities are agreed that a lengthy recompression (eight to twelve hours) is essential to success, and while some experts advise recompression to two-thirds of the pressure formerly experienced, the majority of writers concur in recommending application of the previous working pressure.

One method prescribes former maximum pressure during one hour followed by slight decompression lasting six to eight hours and even twelve hours for workers who have worked at a depth of 20 metres or over. Certain others restrict their demands to pressure which affords relief from symptoms, decompressing thereafter, however, very slowly (three minutes per tenth of an atmosphere).

Recompression should be very slow; the advocates of stage decompression also recommend this system in recompression treatment. In the East River tunnel experience already referred to, best results were obtained by rapid decompression from about 5 atmospheres to 1 atmosphere, followed by a very slow reduction to atmospheric pressure lasting from sixty to ninety minutes and even to two hours. Multiple recompression is sometimes required for bad cases. It has been estimated that with rapid recompression 90 per cent. of results have been obtained in 90 per cent. of the cases.

Recompression is not, however, to be recommended for cases of cardiac and auricular disturbance.

Though certain experts (chiefly German) are not very much in favour of recompression, the results obtained, for instance, in the United States, where in a total of 3,692 caisson workers submitted to recompression, 90 per cent. recovered, prove the benefit of this system. Certain cases required two to three recompressions; 6 to 8 per cent. one recompression only; 9 per cent. were partially cured, and for 0.5 per cent. only no relief was obtained. Twelve cases of partial paralysis were cured (out of 18) by recompression, and 7 out of 16 cases of bilateral paraplegia were cured (out of 18) by recompression. Another ana-
cured by one recompression. Of 17 cases of collapse and loss of consciousness, 8 were cured by one or two recompressions, but 9 terminated fatally.

The patient should, where possible, be carried on a stretcher and not allowed to walk. The recompression chamber should be available several hours or even days after work at considerable pressure has ceased, and a doctor should always be in charge of treatment by recompression. During recompression the patient should have light muscular exercise where possible to stimulate circulation. A medical lock or recompression chamber constructed to contain four or five people, one or two in a recumbent position, is essential for all undertakings where work under a pressure of \( \frac{1}{2} \) atmospheres plus pressure is carried out. The lock should have a second door to allow of entrance of attendants without causing reduction of pressure. It is expedient to have graphic registration apparatus for registering pressure degrees in the lock. The pressure valves should be manipulated from the outside and should not be accessible to the patient. The lock should be lit by electricity and should be provided with all necessities to ensure the patient getting satisfactory attendance (heating, clock, pressure gauge, ventilation, thermometers, barometers, telephone, medical instruments, oxygen, etc.).

On quitting the medical lock, the patient should have a hot bath and remain in bed to prevent a relapse.

**Prophylaxis**

A whole series of measures have been recommended for organising a good system of prevention against caisson disease. It is absolutely essential that a thorough medical examination should be made of all applicants for work in compressed air. Certain authorities urge not only medical examination of applicant, but insist that he should be subjected to compression and decompression tests to ascertain his resistance capacity. Where this is not done, new workers should be put on half-time work and then re-examined. One author reports that in an undertaking where applicants have to submit to compression prior to engagement, as many as 16 per cent. of them have sometimes to be rejected. The medical examination of applicants should be particularly strict, where it is a case of work carried out at a depth of over 18 metres.

A doctor should be attached to all undertakings carrying out compressed air work. It is advisable for the doctor in such an establishment to be provided with a list of diseases which incapacitate workers, to serve as a guide in his choice of suitable workers. Such lists have been embodied in enactments disqualifying workers suffering from certain ailments (Dutch law, for instance — see later). It has been held, however, that such lists are unduly inclusive, it being considered more advisable to leave the decision as to certain lesser affections to the discretion of the doctor. French law, on the other hand, errs in not being sufficiently precise, while the regulations for the German marine service characterise suitable candidates as "thoroughly healthy people" and only heart affections and affections of important parts of the body are specified for exclusion.

Bad circulation is very favourable to development of caisson disease and workers addicted to alcohol are unsuitable, most authorities being agreed in excluding them, though one author admits the practical difficulty of prohibiting entirely all alcoholic subjects because of the possibility of a consequent shortage of workers. Various organic troubles and derangements likewise represent disqualification for this work. The majority of experts, however, cite as important reasons for exclusion, chronic affections of the ear and skin, chronic nasal catarrh, laryngeal catarrh and chest affections, and digestive troubles. It is, of course, understood that all workers suffering from any transient ailments of the above nature must be temporarily withdrawn and not readmitted to work until medically examined and passed by the doctor.

Recommendations regarding the requisite age vary considerably and it has not been found possible to determine exactly the age limit in relation to susceptibility to the disease in question. Generally speaking, authorities are, however, agreed that the minimum age for admission to this work should be fixed at twenty and that the maximum age should not exceed forty to forty-five years.

The best workers are abstemious men of slight build from twenty to thirty-five years of age. Workers between thirty-five and forty-five may be accepted if not subjected to very high pressures. During the construction of the East River Tunnel, however, there was noted remarkable immunity

<table>
<thead>
<tr>
<th>Age</th>
<th>Men</th>
<th>Number of cases (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-20</td>
<td>55</td>
<td>145</td>
</tr>
<tr>
<td>20-25</td>
<td>142</td>
<td>10</td>
</tr>
<tr>
<td>25-30</td>
<td>302</td>
<td>93</td>
</tr>
<tr>
<td>30-35</td>
<td>38</td>
<td>36</td>
</tr>
<tr>
<td>35-40</td>
<td>3</td>
<td>166</td>
</tr>
</tbody>
</table>
amongst older men, though it must be remembered that the workers in question were most carefully selected and for this reason such immunity cannot be taken as typical.

Caisson workers must also undergo periodical medical examination, especially on resumption of work after sick leave; some experts are of opinion that medical examination should take place quarterly, others even advise a weekly medical examination for work at upwards of 1 1/2 atmospheres (see below, Legislation).

The doctor employed by the undertaking should instruct the workers, and especially the foremen, as to the measures to be taken to prevent disease and also as to first aid to be given to victims of caisson disease. Care should be taken to prevent the men going down into caissons immediately after meals and also to see that they are well and warmly clad; that they do not wear waterproof footwear or garments which may interfere with cutaneous respiration.

The manipulation of compression and decompression supply devices should be entrusted to trained supervisors.

All possible measures should be taken to avoid risks of accident since only too often in small undertakings, the most elementary precautions are neglected. Strenuous effort to apply safety measures is in fact of first-rate importance from the economic as well as the humanitarian point of view. It is a well-known fact that oversight in this regard leads to very heavy expense. It is, therefore, advisable that the working and maintenance of all apparatus, machines, piping, valves, etc., should be carefully and regularly submitted to inspection.

Strong iron girders span the interior parts of large caissons and men are not allowed to walk under these, but must pass from one portion of the working chamber to another through large circular openings cut in the iron framework. The use of oxygen is not only advisable as a therapeutic measure, but also as a preventive remedy. In fact, its use during decompression was recommended by Zuntz in 1897 and by Von Schroeter prior to decompression. The use of oxygen is said to stimulate 100 per cent. elimination of N at normal atmospheric pressure, and dissolution occurs in a short period as proved by human and animal experiment. The use of oxygen is, in fact, recommended by different legislative enactments (German, French, etc.). Oxygen at high pressure may, however, present a certain danger, since it is apt to provoke respiratory trouble and even cerebral phenomena (convulsions). It is known, however, that when haemoglobin comes in contact with oxygen, the former is not all transformed into oxyhaemoglobin, the amount transformed being in strict proportion to the temperature and especially to the pressure of the oxygen in the atmosphere in question (partial pressure). The higher the oxygen tension in the atmosphere, therefore, the more oxyhaemoglobin will be formed. It is for this reason that authorities on the subject advise the administration of oxygen at a fairly low pressure (1 1/2 atmospheres at most) during a period of at most thirty to forty minutes.

Another obstacle to the practical application of oxygen under pressure is its high cost, but it is nevertheless necessary to remember in this connection its great utility in the case of severe illness (see article "Aviation"). It would not, however, be without value to institute new experiments in regard to the study of the capacity of oxygen in extracting N from the fatty tissues when it is inhaled during the rest period or diffused into the atmosphere during work.

Compression

A reference has already been made to the symptoms liable to arise during compression. The most adequate measures for preventing these have already found place in legislative enactments (see later). It is essential that the caisson worker should not enter the caisson immediately after a meal and that beginners should be instructed as to the best means of avoiding ear trouble, symptoms of which are most frequent during compression. It has been recommended that workers should suck a piece of sugar in order to aid them in swallowing air. The most effective method, however, is that suggested by Valsalva: workers should be instructed to inflate the middle ear by closing both nostrils with thumb and forefinger, shutting mouth firmly and then making expiratory effort, so as to send the air into the middle ear through the Eustachian tube.

The object of this precaution is to prevent blocking of the passage between the pharynx and the ear, but it will be without success if the worker is suffering from a cold in the head.

The air during compression becomes heated and very dry: this disadvantage may even become intolerable where the air-lock is exposed to the sun. On the other hand, the air in the working
chamber is generally damp and cool. When the workers undergo decompression in the air lock in order to proceed towards the normal atmosphere, the rapidly decompressed air becomes cooled to such an extent that a thick mist is produced off which it wets the men if not provided with a safety apparatus preventing them from opening in a sudden and violent manner (Belgium, France).

The compressed air should be normal in composition. Requisite precaution should be taken with a view to preventing it becoming vitiated by the oxidation products of the lubricating oils. As far as possible the compressed air should be brought to a temperature of 18° C. (Belgium) or 10°-20° C. (Germany) and the temperature during the hot season should be inferior to that of the outer air. During work the compression of the air should be effected and maintained in such a way as to avoid sudden variations above two-tenths of an atmosphere (Belgium).

In summer the locks should be protected from the heat of the sun; in winter efforts should be made to combat the loss of heat (Belgium, France, Holland, etc.). The temperature of the working chamber should be as far as possible within the limits of 10°-18° C., and the variations should not exceed beyond 4° C. (Netherlands). (This recommendation is, however, found impossible to enforce in winter.)

The principal air supply pipe should be furnished with a stop cock near the pumps. Between the compression apparatus and the stop cock there should be placed a safety valve. The following measures should require that the pumps and air supply pipes are in duplicate and constructed in such a way that damaged parts can be removed and replaced without interrupting the supply of air.

The height of the working chamber, measured between the roof and the lower cutting edge, should be at least 1.84 metres (1.80 metres at least in France and Yugoslavia). The air locks intended for the staff should have an interior height of at least 1.80 metres. The locks should have a height of at least 1.85 metres and a minimum capacity of 0.75 cu. m. of air for each worker present (Germany).

The cubic air space in the air lock should reach at least 600 cubic decimetres per worker (France).

Ventilation of the working chambers, shafts, and air locks should be ensured in such a way as to provide continuous renewal of the air calculated at the rate of 40 cu. m., at atmospheric pres-
sure per hour and per worker. After blasting in a working chamber, the air of the latter should be completely purified before workers are again allowed to enter. During periods of decompression exceeding ten minutes, the ventilation of the air lock should be provided for by means of safety lifters simultaneously acting but unequal air outlets and intakes regulated by stop cocks (Belgium).

The quantity of air sent into the working chamber ought to be at least 40 cu. m. per hour and per worker. It should be so regulated that the carbonic acid content of the air does not exceed 1 per 1,000. In the event of the air supply being arrested, the employer's representative in the working chamber should order all workers to leave it after an interval of ten minutes at most (France, Yugoslavia).

**First Aid**

A recompression bell sufficiently spacious to contain comfortably a patient and two attendants is provided by certain legislative measures. This bell should be provided with an air lock for the purpose of unlocking patients and a small subsidiary lock for the introduction of medical supplies. It should be established in a place which can be easily heated, should be lit by electricity and ventilated by a device permitting of renewal of the air at the rate of 50 cu. m., per hour and per person. This medical lock or bell should be provided with an apparatus for oxygen inhalation and a telephone and the temperature should as far as possible be kept in the neighbourhood of 18° C. The provision of the above lock is, however, only compulsory where the pressure necessary to the execution of the work in hand attains 1.5 atmospheres gauge (Belgium, Netherlands); 3 or 2½ atmospheres during fourteen days (Germany); 3 atmospheres (France, Yugoslavia, etc.).

**Other Measures of Hygiene and Safety**

A series of measures passed by various countries to assure the best possible health and safety conditions for caisson workers is given hereunder. These measures complete the others mentioned in various paragraphs of this article.

The rate of the pressure inside and outside the caisson indicated by manometers graduated in tenths of an atmosphere should be under the control of a trained worker entrusted with regulating the air pumps and looking after the air lock. Where pressure exceeds 2 atmospheres the manometer should be of the recording type. The shafts for descent should offer every guarantee of safety and where the supplementary pressure amounts to a maximum of 0.5 kg. the shaft should have a safety lift for the transport of wounded and sick workers to the air lock. A trained foreman should be specially entrusted with the work of compression and decompression. Responsible individuals capable of executing all useful safety precautions against accident should be entrusted with supervision of the undertakings. A clock should be placed in each air lock as well as an automatic device for recording the length of time at different pressures when the latter exceed 1.3 kg. The lock should be electrically lighted and in telephone communication with the working chamber and also with the outside. Near the air lock there should be a cloakroom and rest room (with sleeping accommodation, woollen blankets, and apparatus for drying clothes), also lavatories and a separate canteen. These rooms should be provided with heating; they should be at least 2.2 metres high and should have a cubic air space of 6 metres per worker. The consumption of alcoholic drinks and of tobacco should be prohibited during working hours. The employer should provide hot tea or coffee gratis to the workers.

A register of cases of sickness, open to inspection by the factory inspector, should be kept.

Men under the influence of drink should be forbidden admission to the installation.

When the pressure exceeds 2 atmospheres seating accommodation should be provided for the workers during the time spent in the air lock.

As regards health measures, most legislative provisions demand that each worker on engagement should receive exact instructions regarding compression and the dangers to which he is liable. Pressure should be gradually increased at a sufficiently slow rate to exclude the production of any injurious effects to the workers. In Germany, when new workers are employed pressure increase is restricted to not more than 0.1 kg per minute. Whenever symptoms are observed, the supply of air is stopped immediately, and if these persist, the patient is submitted to decompression and a doctor, or at least a first-aid attendant, is called in.

The Belgian regulations confine the compression rate to five minutes at least per atmosphere, above normal
pressure. Compression is immediately interrupted on request being made by any inmate of the lock. The French and Yugoslav Governments insist that for compression the time-rate should be four minutes at least for increase of actual pressure from 1 kg. per square centimetre to 2 kg. per square centimetre and not less than five minutes for each subsequent kg. per square centimetre.

The Dutch regulations demand that for pressures exceeding 1½ atmospheres workers must arrive a quarter of an hour before they have to enter the air lock and may only proceed to it after they have been examined and found to be free from cold and effects of alcoholism. A half-minute for each 0.1 atmosphere (the prescribed minimum) has given good results.

The importance of medical supervision of caisson workers is insisted on by legislation in all countries. It was made compulsory by law recently (January 1926) in Western Australia. Amongst legislative provisions in force may be mentioned the following:

The German regulations demand that, when pressure exceeds 0.5 kg., per square centimetre, a medical practitioner shall be appointed to watch over the health of the workers. A trained person at least thoroughly conversant with the appropriate first-aid measures in case of accident or illness shall be present or near the works during each shift. No worker shall be admitted till he has been passed as fit by the doctor who shall exclude all persons suffering from the following defects: obesity; defects hampering bodily movement; shortness or mutilation of any limbs; defects which hinder respiration; nasal obstruction; contraction of respiratory passages due to cataracts or vocal affections; disorders of respiratory organs: acute heart disease; degeneration of heart muscle; arteriosclerosis; acute inflammation of the middle ear and other ear diseases; hernia; diseases of the bladder or kidneys; infectious diseases; neurasthenia; organic nervous diseases, and alcoholism. All workers over forty shall not work under additional pressures exceeding 1.3 kg. per square centimetre, except as foremen. Workers temporarily suffering from a cold or intoxicated shall be excluded. Workers suffering from compressed air illness shall not be readmitted till passed fit by the doctor. Medical certificates are valid for twelve months, but if pressure exceeds 2 kg. per square centimetre on more than fourteen days and 1.3 kg. per square centimetre on more than thirty days within a period of ninety days, the certificate shall only be valid for one month. A worker absent three or more days must be re-examined if the pressure exceeds 1.3 kg. per square centimetre. A health record shall be kept.

In Belgium the following are excluded from work in compressed air: (1) workers under sixteen; (2) Intoxicated workers; (3) workers without a medical certificate of physical fitness for this work.

When pressure attains or exceeds 1½ atmospheres plus pressure, the medical certificate shall be renewed frequently. For lesser pressure, such certificate will be valid for the whole working period. No inexperienced workers may be subjected to compression test at a pressure exceeding one atmosphere plus pressure during one hour. When work is carried out at pressure exceeding 2½ atmospheres, a certifying surgeon or other physician must be present while each shift leaves the decompression lock.

The employer must have each worker who is indisposed examined by a doctor as promptly as possible. Each worker must be questioned on entry as to his state of health, and for any worker presenting ailments of the throat, nose, ears, or any alternative opinion is required before he may undergo compression.

In France and in Yugoslavia, a doctor appointed by the employer shall be entrusted with making periodical examinations of the employees. No worker may be admitted to work in compressed air unless he possesses a certificate from the doctor stating that he is fit for this work. No worker may be kept at work in compressed air unless his medical certificate is renewed fifteen days after admission to this work and not in months thereafter. Besides such periodical visits, the employer is obliged to have examined by the doctor each worker complaining of affections of the nose, throat or ears and requesting to be examined. A record for all workers, kept up to date and showing all cases of accident and illness, however slight, must be kept.

In the Netherlands, when pressure exceeds ½ atmosphere, a doctor must be appointed to look after the health of the workers and instruct them in necessary precautions to be observed in leaving the caisson and the air lock and during their stay in the rest room.

All workers must be over twenty and under forty-five for pressures between ½ and 3 atmospheres and over twenty and under thirty-five when pressure exceeds 3 atmospheres, and must have been medically examined and in pos-
session of a certificate of physical fitness, which is only valid for seven days for pressures of 1½ atmospheres or over and twelve months for inferior pressures. The doctor shall exclude from work all men presenting the following defects: deformity of the body, especially the spine and limbs; arrested physical development; general debility; obesity; chronic skin disease; scars which impede movement; diseases of the glands; carbuncles or boils which by their position or extension can impede movement; chronic affections of the bone structure and muscular system or of the articulations; cardiac and vascular affections (aneurism, varicose veins, etc.); nervous disorders; diseases of the blood (syphilis, malaria, chronic metal poisoning); affections of the respiratory system, of the lungs or pleura; chronic digestive disorders; chronic affections or lesions of the genital organs; hernia; kidney disease; disease of the bladder or gonorrhoea; troubles due to alcoholism; affections of the nose and ears; workers must have nostrils free from any obstruction to air passage. Perforated tympani are not an obstacle to employment in compressed air unless due to acute inflammation of the middle ear.

**LEGISLATION**

The laws and regulations issued in the different countries and dealing with work in compressed air are the following:

**Australia (Western):** 1926.

**Austria:** Provisions dated 1912.

**Belgium:** Royal Orders of 16 March 1909 and 15 January 1914; Ministerial Order of 20 January 1914.

**France:** Decree of 15 December 1908; Order of 10 March 1909; Circular of 28 December 1908; Decree of 1 October 1913; Order of 9 October 1913.

**Germany:** Regulations of 28 June 1920.

**Great Britain:** See article "Divers ".

**Greece:** Regulations of 25 February and 9 March 1912; Act No. 3617 of 23 March 1910 (on sponge fishing effected by divers). (See article "Divers ".)

**Hamburg:** Order of 17 December 1909.

**Italy:** Ministerial Order of 4 June 1913 (sponge fishing effected by divers); Regulations of the Admiralty, 1910.

**Mexico:** Decree No. 2308 of the Labour Act of the State of Jalisco (section 225).

**Netherlands:** Act of 22 May 1905; Decree of 10 August 1909.

**Russia:** Regulations of 4 November 1920.

**Switzerland:** Town of Zurich: Regulations of 11 March 1911, relating to safety and hygiene of persons engaged in build-

ing, etc. (sections 44-47). Town of Basle: Regulations of 27 June 1914 (sections 13-16).


**Yugoslavia:** Regulations of 25 October 1921, on the measures of hygiene and safety in industrial establishments (sections 177-190).

Caisson disease is usually compensated as an industrial accident. However, a certain number of countries have included this disease amongst those compensated as accidents: Australia (Western); Chile; Great Britain; Minnesota; New Brunswick; New Jersey; New York; Ontario; Queensland; Russia; Venezuela.

It is subject to compulsory notification in the following: Bavaria; California; Connecticut; Maine; Maryland; Massachusetts; Michigan; Netherlands; New Hampshire; Pennsylvania; Wisconsin.

At the 1910 meeting of the International Association for Labour Legislation, certain guiding principles relative to work in caissons were adopted by the committee entrusted with the study of work in compressed air. Subsequently, several countries have issued detailed legislative measures on the subject which are analysed below.

As regards the amount of air supplied, regulations vary somewhat in the neighbourhood of the recommendations of different experts, one of whom advocates 30 c.u.m. per man per hour, while another demands 60 c.u.m. per man per hour in the working chamber. The French regulations demand 40 c.u.m. and in case of interruption in the air supply the workers must be dismissed after a lapse of ten minutes. Regulations for Yugoslavia lay down 40 c.u.m. per man per hour, and for Belgium continual renewal of the air calculated at atmospheric pressure to give 40 c.u.m. per person is required. The Dutch regulation demands 25 c.u.m. per man per hour for a pressure of ½ atmosphere, and 45 c.u.m., for a pressure exceeding that.

As regards working hours for compressed air work, the legislative provisions are as follows:

In Germany the working hours must not exceed:

(a) eight hours when the additional pressure does not exceed 2 kg. per square centimetre.

(b) six hours when the pressure exceeds 2 kg. but does not exceed 2.5 kg. per square centimetre.

(c) four and three-quarter hours when the pressure exceeds 2.5 kg. but does not exceed 3 kg. per square centimetre.

(d) four hours when the pressure exceeds 3 kg. but does not exceed 3.5 kg. per square centimetre.

(e) two hours when the pressure exceeds 3.5 kg. per square centimetre.
Locking-in time shall be included in the eight-hour shift, but not in the shorter shifts (6)-(e).

New employees shall only be employed half above time on first working day, and if no bad results occur they may remain two-thirds of full time on second and third days and full time on fourth day. Where the shift exceeds four hours, breaks shall be allowed amounting in all to half an hour and a rest period of not less than twelve hours shall intervene between each two shifts.

The length of the working day has been fixed by law in the States of New Jersey, New York, and Pennsylvania as follows:

<table>
<thead>
<tr>
<th>When the pressure (abs) exceeds the normal atmospheric pressure (not amount to over)</th>
<th>Number of hours work in 24 hours</th>
<th>Number of shifts</th>
<th>Duration of rest periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 lbs.</td>
<td>8</td>
<td>2 of 4 hrs.</td>
<td>30 min.</td>
</tr>
<tr>
<td>21-30 lbs.</td>
<td>6</td>
<td>2 ... 1 ...</td>
<td>1 hr.</td>
</tr>
<tr>
<td>30-35 lbs.</td>
<td>4</td>
<td>2 ... 1 ½ ...</td>
<td>2 hrs.</td>
</tr>
<tr>
<td>35-40 lbs.</td>
<td>3</td>
<td>2 ... 1 ½ ...</td>
<td>3 hrs.</td>
</tr>
<tr>
<td>40-42 lbs.</td>
<td>2</td>
<td>1 ½ hr. ...</td>
<td>4 hrs.</td>
</tr>
<tr>
<td>42-45 lbs.</td>
<td>1</td>
<td>2 ... 45 min. ...</td>
<td>5 hrs.</td>
</tr>
</tbody>
</table>

Except in an emergency, no person is permitted to remain in a tunnel, caisson or compartment where air pressure exceeds 50 lbs.

In France, the Order of 1903 states that it is incompetent to exceed in twenty-four hours the working periods noted hereunder in compressed air, inclusive of time spent in the air-lock:

<table>
<thead>
<tr>
<th>Hours of work (kg. per square centimetre)</th>
<th>Gauge pressure (between 2.0 and 2.5)</th>
<th>2.5</th>
<th>3.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>2.3</td>
<td>3.0</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Netherlands law goes further still. For pressures between 2 ½ and 3 atmospheres working hours may not exceed eight in the twenty-four, less the minimum time required for compression and decompression and a rest interval of half an hour after the first four hours. When the pressure is below 3 atmospheres but above 1 atmosphere and if the work in the caisson is heavier than usual, decompression must take place after four consecutive hours spent in the caisson. After decompression a worker may not again be subjected to pressure until twice the length of his shift has elapsed, or a period which may not be less than eight hours. When pressure exceeds 3 atmospheres, the stay in the caisson may not exceed one and a half hours consecutively or three hours in the twenty-four, and after decompression a worker may not again be subjected to compression till after the lapse of eight hours.

The law of the State of Jalisco (Mexico) demands that for all work executed under a pressure superior to normal atmospheric pressure or in vitiated atmosphere or in atmosphere containing toxic products, the worker shall be allowed to acclimate himself gradually to the work of the class in question and shall be thereafter carefully examined by a doctor. The amount of time spent daily on such work shall be in relation to the pressure in accordance with the provisions of the special regulation on the subject, but in no case shall it exceed upwards of one hour.

The German law stipulates the following minimum periods:

<table>
<thead>
<tr>
<th>Minutes</th>
<th>Plus pressure kg. per square centimetre</th>
<th>Minutes</th>
<th>Plus pressure kg. per square centimetre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.1</td>
<td>29</td>
<td>2.9</td>
</tr>
<tr>
<td>2</td>
<td>0.2</td>
<td>30</td>
<td>3.1</td>
</tr>
<tr>
<td>3</td>
<td>0.3</td>
<td>31</td>
<td>3.1</td>
</tr>
<tr>
<td>4</td>
<td>0.4</td>
<td>32</td>
<td>3.2</td>
</tr>
<tr>
<td>5</td>
<td>0.5</td>
<td>33</td>
<td>3.2</td>
</tr>
<tr>
<td>6</td>
<td>0.6</td>
<td>34</td>
<td>3.2</td>
</tr>
<tr>
<td>7</td>
<td>0.7</td>
<td>35</td>
<td>3.2</td>
</tr>
<tr>
<td>8</td>
<td>0.8</td>
<td>36</td>
<td>3.2</td>
</tr>
<tr>
<td>9</td>
<td>0.9</td>
<td>37</td>
<td>3.2</td>
</tr>
<tr>
<td>10</td>
<td>1.0</td>
<td>38</td>
<td>3.2</td>
</tr>
<tr>
<td>11</td>
<td>1.1</td>
<td>39</td>
<td>3.2</td>
</tr>
<tr>
<td>12</td>
<td>1.2</td>
<td>40</td>
<td>3.2</td>
</tr>
<tr>
<td>13</td>
<td>1.3</td>
<td>41</td>
<td>3.2</td>
</tr>
<tr>
<td>14</td>
<td>1.4</td>
<td>42</td>
<td>3.2</td>
</tr>
<tr>
<td>15</td>
<td>1.5</td>
<td>43</td>
<td>3.2</td>
</tr>
</tbody>
</table>

In unlocking the additional pressure shall at first be reduced by 0.15 kg. per square centimetre per minute until reduced to half its initial amount and thereafter shall be reduced gradually and regularly for the remainder of the time. No person other than the responsible and reliable air-lock attendant shall undertake compression or decompression for over 1.3 kg. per square centimetre or where more than 4 workers are in the air-lock at the same time.

To the Belgian law (Royal Decree of 15 January 1916) there is appended a full and detailed decompression table showing prescribed rates for unlocking by stage decompression method.

A. — FOR A STAY UNDER PRESSURE OF UPWARDS OF ONE HOUR

<table>
<thead>
<tr>
<th>Atmospheres (plus pressure)</th>
<th>Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1-0.5</td>
<td>5</td>
</tr>
<tr>
<td>0.5-1.0</td>
<td>10</td>
</tr>
<tr>
<td>1.0-1.5</td>
<td>15</td>
</tr>
<tr>
<td>1.5-2.0</td>
<td>20</td>
</tr>
<tr>
<td>2.0-2.5</td>
<td>25</td>
</tr>
<tr>
<td>2.5-3.0</td>
<td>30</td>
</tr>
<tr>
<td>3.0-3.5</td>
<td>35</td>
</tr>
<tr>
<td>3.5-4.0</td>
<td>40</td>
</tr>
</tbody>
</table>

These periods shall be increased by 20 per cent. from 1 atmosphere plus pressure upwards when the time spent under compressed air exceeds eight hours per shift or when the intervals between the shifts do not amount to at least double the length of the shift in question.
B. — For a stay under pressure of less than one hour and over thirty minutes

<table>
<thead>
<tr>
<th>Atmospheres (plus pressure)</th>
<th>Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 1.0</td>
<td>5</td>
</tr>
<tr>
<td>1.0 - 1.5</td>
<td>10</td>
</tr>
<tr>
<td>1.5 - 2.0</td>
<td>15</td>
</tr>
<tr>
<td>2.0 - 2.5</td>
<td>20</td>
</tr>
<tr>
<td>2.5 - 3.0</td>
<td>25</td>
</tr>
<tr>
<td>3.0 - 3.5</td>
<td>30</td>
</tr>
<tr>
<td>3.5 - 4.0</td>
<td>35</td>
</tr>
</tbody>
</table>

C. — For a stay of less than thirty minutes

<table>
<thead>
<tr>
<th>Atmospheres (plus pressure)</th>
<th>Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 - 1.0</td>
<td>3</td>
</tr>
<tr>
<td>1.0 - 2.0</td>
<td>10</td>
</tr>
<tr>
<td>2.0 - 2.5</td>
<td>15</td>
</tr>
<tr>
<td>2.5 - 3.0</td>
<td>20</td>
</tr>
<tr>
<td>3.0 - 3.5</td>
<td>25</td>
</tr>
<tr>
<td>3.5 - 4.0</td>
<td>30</td>
</tr>
</tbody>
</table>

These tables, together with instructions to workers, must be posted up on the premises.

The French and Yugoslav regulations provide that the time spent in decompression shall not be less than the periods indicated hereunder:

- Twenty minutes per kg. per square centimetre of plus pressure above 3 kg.;
- Fifteen minutes per kg. per square centimetre of plus pressure between 3 kg. and 2 kg.;
- Ten minutes per kg. per square centimetre of plus pressure below 2 kg.

If pressure does not exceed 1 kg. plus pressure per square centimetre, the time spent in decompression may be reduced to five minutes.

In the Netherlands, for pressures under 1 atmosphere, the rate of decompression shall be one and a half minutes per tenth of an atmosphere and for pressures between 1 and 3 atmospheres, five minutes and at least one and a half minutes for each tenth of an atmosphere above the first 1 atmosphere. For pressures between 1½ and 3 atmospheres, twenty minutes, and at least two minutes for each tenth of an atmosphere above 1½ atmospheres, then one and a half minutes for each tenth of an atmosphere. For pressures of over 3 atmospheres, fifty minutes and three minutes at least for each tenth of an atmosphere above 3 atmospheres proceeding thereafter as above.

The Codes referred to for the three States of U.S.A. give values for stays under pressure, rest periods and uniform decompression for the absolute pressures indicated hereunder:

<table>
<thead>
<tr>
<th>Gauge pressure</th>
<th>Time under pressure</th>
<th>Interval</th>
<th>Uniform decompression</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 lbs.</td>
<td>8 hrs. less interval</td>
<td></td>
<td>30 consecutive minutes</td>
</tr>
<tr>
<td>0 - 28</td>
<td></td>
<td></td>
<td>spent in open air</td>
</tr>
<tr>
<td>28 - 39.99</td>
<td>2 spells of 3 hrs. each.</td>
<td>At least 1 hr.</td>
<td></td>
</tr>
<tr>
<td>36 - 41.99</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>42 - 45.99</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>46 - 49.99</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For Great Britain and Russia, see details in article "Divers".

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Confectioners and Pastrycooks

French: Confeiseurs et Pâtissiers.— German: Konditoren und Kuchenbäcker.— Italian: Confeittieri e Pasticcieri. — Spanish: Confeccionadores y Pasteleros.

Pastrycooks and confectioners are exposed in course of the exercise of their occupation to various risks referred to from time to time in medical literature. Attention has moreover been drawn to the fact that delicate individuals often engage in this trade. The affection most commonly reported amongst these workers is dermatitis. Certain skin outbreaks have been attributed to sugar since the time of Turner Thackrah (1832), while as far back as 1817 Willan describes under the name of eritis 

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Amongst confectioners as amongst bakers the fermented dough after a time causes eczematous patches, with a special aspect which has earned for them the name of "bakers' sporiasis".

There has also been noted amongst bakers and confectioners a type of impetigo due to glucose, situated on the forearm, the hands, the legs and the feet.

Another type of dermatitis noted amongst confectioners which recalls that which affects cooks has been described by Rosenbach and Goettingen under the name of "eritis purulente". This lesion is situated on the fingers and hands and takes the form of a dark red or livid inflammation which as it develops causes a slight sensation of burning. It disappears after two or three weeks.

Handling of irritant substances often in a dirty condition favours the outbreak of an eczematous dermatitis described by Bazin, characterised by vesicles appearing on an erithematous surface. These vesicles break and then form again. The dermis changes and becomes reddened; the epidermis breaks and becomes covered with little cracks, papular swellings and lichenoid patches.

An acute lesion of the nails has been studied by G. Heller and M. Strauss. This eczematous lesion sets up purulent discharge, the nail was raised and became the seat of severe pain. Strauss likewise has reported chronic cases in which surgical intervention was required.

It should be mentioned that Thibierge and Legrain noted lesions of the nails and paronychial lesions with deformation of and black patches on the nails similar to the lesions above referred to affecting a woman worker engaged in packing cakes and biscuits in boxes.

The nails present special lesions particularly for workers burdened with much work under bad hygienic conditions. When for instance the confectioner prepares preserved fruits and has to plunge his fingers into a very hot sugary solution he may be attacked by lesions of the nails. This affection was studied by Kingery and Thienes (1925) in certain American factories, a third of the workers engaged in making preserved fruits suffered from paronychia, which also affected members of their families.

Poncet, Albertin, Chaussande and other French writers refer to a form of inflammation of the nails peculiar to confectioners and frequent in the large sugared fruit factories of Southern France. This eruption has been held to be due to dipping the hands in the chemical acids present in the fruit juice, while other authorities are inclined to regard the saccharine solutions as responsible and the trouble as analogous to the usual bakers' eczema. This affection begins with erosions and fissures about the nail fold, followed by inflammatory processes with ulceration, granulation, sero-purulent secretions; the nail often becomes loosened and destroyed, the disease following a chronic course and lasting even for years with subacute intervals. The characteristics are simultaneous affection of several nails, discoloration of the nails, granulation, and flattening of the nail plate. Poncet considers onychia sufficiently characteristic to serve as proof in legal medicine. The middle and third fingers are principally affected. After loss of the nail, the finger ends develop a characteristic spatulate form which is lasting.

Bakers and confectioners suffer very bad teeth due chiefly to caries which affects especially the incisors. In 1910
Kunert found amongst bakers and confectioners between twenty-five and twenty-eight years of age, 40 per cent. of the teeth sound, and amongst those aged forty years, 21.2 per cent. only. In general there were amongst the persons examined 6.7 healthy teeth per worker.

Confectioners inhale and ingest sugar dust to a certain extent, and the deposit of flour and sugar dust on the teeth and gums in the absence of frequent and regular cleansing favours fermentation processes and dental caries (see article "Mouth and Teeth"), which are of relatively high frequency amongst confectioners as amongst bakers and sugar workers. It has been alleged that proliferation and virulence of disease germs found in the bucal cavity of normal individuals are also formed thereby.

In preserved fruit factories the workers engaged in peeling and cutting the fruits are sometimes exposed to disease germs found in the bucal cavity of normal individuals are also formed thereby. Kunert found amongst bakers and confectioners between twenty-five and twenty-eight years of age, 40 per cent. of the teeth sound, and amongst those aged forty years, 21.2 per cent. only. In general there were amongst the persons examined 6.7 healthy teeth per worker.

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Thus for instance there has been noted dermatitis caused by oranges and tangerines (Imbert), lemons (Pieraccini), and bitter oranges, the harmful principle being the essential oils contained in the fruits. When peeling the fruit the worker makes an incision in the skin of the fruit which is held in the left hand, the juice falls in the hands, especially on the left hand, whence it is afterwards conveyed to the face and uncovered parts of the body (Loriga).

Imbert and Goubeyre found the form of dermatitis in question caused by bitter oranges amongst twenty-nine out of forty-one workers examined. The eruption commences by a severe pruritus; then there follows erythema accompanied by oedematous swelling, which fairly often becomes covered with small vesicles. These vesicles break, discharge a liquid which forms yellowish-grey crusts. The lesion occurs on the hands, on the lower part of the forearms and on the face. Sometimes it is accompanied by general symptoms of a toxic order (headache, vertigo, various types of neuralgia, cramp, excitement and sometimes convulsions).

Vanillism attacks workers who sort, clean, and pack pods of vanilla, and workers handling vanilla in the confectionery trade are liable to suffer from dermatitis. The pods are usually imported in drums containing spirits and these often splash the arms and sometimes the face of the workers, developing irritation, erythema, papulae and even vesicles which persist for two or three weeks subsequent to contact with the liquid. Opinion varies as to whether symptoms are due to the acarus common in the pods or to the volatile oil of the cachew nut known as cardol, which is employed to colour and preserve the pods.

Angelica or cow-parsley used in the confectionery trade is capable of setting up dermatitis and blistering among certain individuals, the toxic principle being probably angelic acid.

General prejudicial factors in the industry in question are exposure to undue heat, impure air, long hours and arduous work. Besides diseases of the respiratory passages, anaemia, probably the result of chronic gas poisoning and excessive perspiration, acute infectious diseases, digestive diseases and disorders of the heart, eczema and conjunctivitis are reported as of common occurrence amongst the workers. Fatigue due to excessive speed is to be reckoned with in the confectionery trade where one employee is often obliged to wrap up 9,000 caramels in one day.

Pieraccini found a young worker cutting seventy to eighty lemons a minute. Qualified workers cut even 25,000 lemons in ten hours and women workers engaged in wrapping lemons in paper can prepare thirty to thirty-two per minute. Generally they can wrap up seven to ten thousand lemons per day of ten hours.

Dangers of explosion exist in sweet-making factories from the dust in starch bulk, sifting and drying rooms. Shellac and alcohol may also represent explosive hazards in these establishments.

Confectioners and pastry-bakers are, from the very nature of their occupation, often exposed to the risk of burns, on the one hand, from the glowing heat of the baking ovens and fire irons and by contact with the frequently red-hot oven-door handles, and, on the other hand, from hot liquids when milk and sugary liquids boil over, as for instance in the operation of icing with boiling liquids. Burns are often encountered when removing cake tins and sweet moulds from the oven.

Not all accidents are the direct result of carelessness and haste. Burns of the second degree are often inflicted by steam issuing from the boilers and affect chiefly the hands, face and chest. Burns of the left hand and forearm are often caused when fetching out metal slides from the oven by means of an iron rod. The practice is to rest the slides on the left arm protected by a
Copper


Copper is widely distributed and is mined extensively in various parts of the world, particularly the United States, China, Japan, the Ural Mountains and Sweden. Recently extensive deposits have been found in Chile.

Copper usually occurs in the form of oxides, carbonates, and silicates but chiefly in that of sulphates. The native metal, the oxides, carbonates and sulphates usually occur in the upper portions of deposits through action of water and air upon sulphides, etc. Sulphur combinations are the most important sources of copper, among which the chief minerals or ores are copper pyrites, copper glance, and erubescite.

The chief elements of poisonous nature found in conjunction with the sources of copper are lead, antimony, and arsenic.

The ores which contain these are bornite (a sulphide of copper, lead and antimony), chalcocite (a sulphide of copper and of antimony), tetrachloride (often containing iron, lead, zinc, mercury, silver and arsenic); a part or the whole of the antimony may be replaced by arsenic constituting tenaitite), gold fieldite containing arsenic, limarite containing lead, etc.

Naturally those engaged in handling and refining copper ores have a possible exposure to the action of sulphur compounds, arsenic, antimony, bismuth, lead and tellurium, to which should be added zinc, selenium, mercury, silver and gold.

It is practically impossible to free copper of all traces of arsenic and antimony where these were present originally. The Anaconda Mining Company report in their electrolytic product (cathode copper): copper 99.97 per cent., arsenic 0.0016 per cent., antimony 0.0015 per cent., with silver 0.3 oz. per ton (The Anode, June 1922).

Copper occurs also in animal and plant tissues, where it undoubtedly has a physiological action. It is found even in the feathers of birds. Hess and his co-workers recently investigated the subject again, using delicate tests, and found in cows' milk 0.55 mg., in woman's milk 0.4 to 0.6 mg., and in infants' and adults' urine 0.06 to 0.14 mg. per litre.

Copper is probably the only metal which occurs pure, as in the Lake Superior region, where masses as great as 400 tons have been uncovered. The copper mines of the United States have produced half of the world's product for some years past and employ upwards of 60,000 men — a lesser number than formerly, owing to labour-saving innovations.

Metallic copper has been known from the earliest times and was probably the first metal to come into any considerable use. Its alloy with tin (bronze) was the first metallic compound in use by mankind and characterises the pre-historic Bronze Age. This is explained by its native occurrence and the ease with which its oxidised compounds are reduced. It owes its name (Latin, cuprum) to the fact that the Romans obtained it from the Island of Cyprus.

Commercially there are four kinds of copper: electrolytic (99.8 per cent. pure), casting (with traces of precious metals), pig (free from precious metals), and Lake or native metallic copper (99.8 per cent. pure). The chief articles manufactured are, in descending order: wire, rods, sheets, tubing and castings.

Copper forms alloys with almost all the metals as well as with arsenic and phosphorus harden the copper without rendering it friable, while alloys formed with bismuth, lead, antimony, and iron likewise harden it but render it at the same time useless for certain purposes. In order to undergo malaxation and drawing, copper must contain a slight proportion of oxygen.

Chemical Properties

A metal. Symbol: Cu. Atomic weight: 63.57 (0=16). Specific gravity: 8.90 (electrolytic copper), 8.2—8.5 (commercial copper). Melting point: 1,083° C.; copper assumes...
a gaseous form (boils) at about 2,300° C. (range variously stated as from 1,980° C. to 2,350° C.).

It is a reddish, lustrous, flexible, ductile, malleable, hard metal.

Electric conductivity 96.4 at 13° C., or 100° C. only to silver taken as 100 at 13° C.

While copper probably forms six oxides, the cuprous (Cu₂O) and the cupric (CuO) only give use to well-defined series of salts.

Oxidising acids convert copper into corresponding salts. Even carbon dioxide in the atmosphere, with the aid of moisture, gradually covers the surface of copper with a greenish coating of a basic carbonate. Copper heated in air oxidises to black cuprous oxide. Sulphur and the halogens attack it much more energetically than oxygen. Copper compounds are usually blue, green or yellow. Cupric compounds formed under usual conditions are more stable and, in presence of water, form blue colours. Cuprous compounds, which are formed at high temperatures, produce colourless solutions.

Copper salts and even copper have a catalytic action for oxygen in many chemical reactions, and increase the action of enzyme peroxidases in living tissues (Hess).

Copper is soluble in hot concentrated sulphuric acid, hot concentrated nitric acid and dilute nitric acid; slightly soluble in dilute sulphuric acid, ammonium hydroxide and organic acids; very slightly soluble in hydrochloric acid; insoluble in cold concentrated nitric acid, water and alcohol.

Thresh found that practically all waters take up traces of copper if allowed to stand sufficiently long therewith, but that under all ordinary circumstances for drinking purposes the amount taken up is far too small to endanger health.

The following melting and boiling points are given by way of comparison (Koelsch), and show that zinc boils at a lower temperature than copper melts — and that zinc boils at a lower temperature than copper melts — and show that zinc boils at a lower temperature than copper melts. —

<table>
<thead>
<tr>
<th>Metal</th>
<th>Melting point °C.</th>
<th>Boiling point °C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>207</td>
<td>1,640</td>
</tr>
<tr>
<td>Tin</td>
<td>223</td>
<td>1,927</td>
</tr>
<tr>
<td>Zinc</td>
<td>419</td>
<td>950</td>
</tr>
<tr>
<td>Copper</td>
<td>1,080</td>
<td>2,350</td>
</tr>
<tr>
<td>Iron, with 2.3 per cent. or more of carbon</td>
<td>1,075-1,275</td>
<td>—</td>
</tr>
<tr>
<td>Iron (pure)</td>
<td>1,500-1,600</td>
<td>—</td>
</tr>
</tbody>
</table>

Uses. — Electrical equipment: chemical apparatus and equipment; copper salts; brass, bronze and other alloys; metallurgy; roofing, cooking utensils; coinage.

Industrial Processes

There are three general methods of separating copper from its ores:

1. Leaching or hydro-metallurgical. Copper from leach solutions of even complex ores is obtained by (a) chemical precipitation using iron (particularly for discarded refinery wastes), hydrogen sulphide, or sulphuric acid, and (b) electrolysis with insoluble anodes obtained from the smelters (The Chemical Industry, 1924, p. 242). It is said that the leaching method may soon replace the smelting method. The metal obtained from this method is called “cement” copper, which is further refined as it may contain no more than 55 per cent. copper. Among significant impurities are antimony and arsenic. Hamilton reports that on the Pacific coast of America finely divided “cement” copper causes a good deal of skin and, when breathed, mucous membrane irritation in workers, with a subjective smell or taste, or both, of putrefying flesh (effects undoubtedly due to arsenic, etc., and not to copper).

2. Smelting or pyro-metallurgical. Copper sulphides and other ores are concentrated, often by flotation with sulphuric acid and oil, then roasted (calcined), the oxide remaining. This is reduced with carbon and a siliceous flux to a resulting matte containing 40-50 per cent. of copper. This is next converted to oxides in a (reverberatory) furnace, “pooled” with wood to remove occluded gases, yielding “blister copper” of 96 to 98 per cent. purity. The product resulting is usually cast into blocks called “anodes” (99.5 per cent. pure copper). By the smelting method, ore can now be turned into copper bars of 99 per cent. purity within eight hours. Anodes are further refined by electrolysis, which deposits the copper as “cathodes”. These are then recast by furnacing into suitable shapes for the market. These ingots are 99.9 to 99.99 per cent. pure copper, with minute traces of arsenic, antimony, gold and silver.

3. Electrolysis. About 70 per cent. of the world’s annual copper output is refined electrolytically. This method is adapted to certain ores (as well as “anodes”) and recovers a great deal of silver and gold which formerly were lost. The usual practice recovers close to 1 oz. of copper per ampere per diem. Dangerous acidic vapours are apt to escape, while the hazards of electrical injuries with low voltage and high amperage are extant.

Sources of Risk

Workers in various copper processes are often thought to be “copper poisoned”. A critical analysis of this subject shows as follows:
Copper mining.—These mines comprise the deepest in the world, those at Butte, Montana, U. S. A., being 3,800 ft. (1.16 km.), and those in the Lake Superior region 5,300 ft. (1.64 km.), with temperatures up to 90° F. at such depths. Copper mining, therefore, may be associated with hot, humid, stagnant air, which is often impregnated with finely divided dust from quartz or other rock composed largely of free silica. In the past, workers have been unable physically to work at more than one-third capacity and have become practically incapacitated for work frequently in less than five years. In more recent years, in the deeper mines especially, fan ventilation, water sprays, wet drilling and stoping have greatly changed these harmful conditions for the better. Hours have been reduced, the number of workers decreased and in some regions (Michigan) working days reduced from six to five per week with output affected but little owing to the increased efficiency of workers (Mineral Industry, 1924, p. 189).

While copper miners have various afflicions none can be charged to any peculiar toxicity of copper itself. The complex ore dusts often produce digestive, respiratory, skin and conjunctival diseases. Miners complain at times of heat-fatigue, from powder fumes; oxygen want, from poor ventilation and occasionally the accumulation of methane gases from old supporting walls; accident hazards, as for miners in general; and hookworm disease, particularly in older mines and in more tropical countries.

Dr. Lauza, in the Butte, Montana, mines (December 1916 to February 1918), examined 1,018 bona-fide miners (volunteer examinees), of whom 432, or 42.4 per cent, showed definite signs of dust injury to the lungs. He summarises by the following table:

<table>
<thead>
<tr>
<th>State of the disease</th>
<th>Miner's pneumitis</th>
<th>Tuberculosis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Per cent.</td>
</tr>
<tr>
<td>Early</td>
<td>191</td>
<td>44.9</td>
</tr>
<tr>
<td>Moderately advanced</td>
<td>128</td>
<td>29.6</td>
</tr>
<tr>
<td>Far advanced</td>
<td>110</td>
<td>25.3</td>
</tr>
<tr>
<td>Total</td>
<td>432</td>
<td>100.0</td>
</tr>
</tbody>
</table>

In his treatise on industrial pathology, Pieraccini relates in detail the result of his observations in the copper mines of Tuscany. He examined a great number of miners and foundry workers, collected data relating to their state of health from the doctors in the district who had been many years in practice there, and arrived at the conclusion that no objective symptom permits of the inference that chronic copper poisoning exists. The injuries met with amongst these workers are to be attributed to lead, antimony and arsenic present in the ore, and which are given off in course of the various operations, rather than to the copper itself.

An enquiry made by Bianchi in 1909 in the iron pyrites and copper mines of the province of Grosseto likewise failed to reveal injuries due to copper. There was not found amongst the miners or founders the blue line, blue teeth, etc., which experts have alleged to exist. An examination of the blood likewise did not reveal the existence of any morphological and quantitative alterations of the corpuscles.

There were found, on the other hand, injuries caused by sulphurous anhydride fumes given off during the roasting of pyrites fumes which on contact with moist air are transformed into sulphuric acid and cause fairly serious burns on the mucous membrane of the eyes and the upper respiratory passages.

J. Wile made a study of mines and copper foundries in Cornwall; the lesions described were, however, chiefly due to arsenic. A. J. Atkinson reported in Great Britain (1907) that copper precipitate caused a cutaneous eruption amongst workers engaged in unloading copper ores.

Schachnasarow and Sarkisbekow in 1926 studied health conditions in the copper mines of Katar, Armenia, worked since 1848, the ore of which contains about 13 per cent. of copper. The temperature in the cutting sheds varied between 16° and 23° C., and the relative humidity between 74 and 100 per cent. The ventilation was found to be very inadequate, which explains the high humidity rate. The foundries likewise were without good exhaust apparatus, so that the poisonous fumes, SO, ZnO, PhO, etc., were disseminated not only throughout the factory, but even reached the workers' dwellings situated in the neighbourhood.

Copper smelting may involve exposure to sulphurous, anthamional, arsenical and other fumes, and also to the
products of combustion, which sometimes contain 25 per cent. of carbon monoxide. These fumes may be very destructive to surrounding vegetation. Especially is an arsenical dermatitis common at the great smelters at Anaconda, and, even more serious, arsenical nasal complications (Dunlop). Hamilton reports selenium poisoning in copper refining in New Jersey, U.S.A.

In the elaboration of copper by heating processes, a peculiar hazard — metal fume fever — may occur.

The coppersmiths’ trade resembles blacksmithing and boiler making, and has the various processes of drilling, boring, shaking, beating and pounding, soldering, grinding, polishing, and buffing.

In applying copper electrolytically, the metallic surfaces to be covered are prepared to receive it by sandblasting by means of compressed air. This operation, which replaces scouring by acids, is intended to free the raw material from calamine. The metal, which rarely is actually melted to any extent in the forge and furnace, may often be heated still higher and to a slight volatilisation point. Heat, noise (leading to progressive deafness), and copper dust are the chief hazards. Seventy-five coppersmiths interviewed in Chicago (Hayhurst) were uniformly healthy men, some of whom had been at the trade as long as forty years. There was no evidence discoverable of “copper poisoning” among either copper or bronze founders. Coppersmiths have long been known to suffer above the average in most forms of ordinary sickness — acute bronchial catarrh, rheumatism, gastro-enteric catarrh, tonsillitis, neuralgia, eczema, diseases of the veins, contusions, fractures, burns, etc. Lead poisoning may also be prevalent.

Any evidence concerning “chronic copper poisoning” as in coppersmithing has been reinvestigated by Mallory in connection with pigment cirrhosis (see below and also article “Copper Boiler Making”).

Cases of oxalic acid poisoning contracted during the polishing of copper or brass utensils have been reported. The men engaged in soldering of copper are exposed to lead and the inhalation of acid and possibly arseniuretted hydrogen fumes. Copper is also used, in connection with gold, silver (see article “Jewellery Industry”) and mercury in water gilding, and in the manufacture of bronzing powder. The sulphate of copper is used for coppering wire. Many of these processes involve not only the inhalation of dust, but also of acid fumes and therefore engender diseases of the respiratory and digestive organs.

Finely divided copper dust — as in grinding, polishing and buffing — produces “copper itch”, analogous to the usual dermatitis occurring from metallic and other dusts apparently otherwise inert (see article “Brass”), and more pronounced in hot weather or during sweating, and usually most prevalent about the neck, axillae, belt line and exposed surfaces of the body (see below).

Peigney, who studied the afflictions of copperworkers in a large French plant during the war where fusées were made and where 2,000 women and 700 men were employed, found that about one-third of the younger women, in particular, suffered at intervals from attacks of gastro-intestinal disturbances of irritative character due largely to ingestion and perhaps skin absorption of copper particles and copper salts, and slightly worse in oily processes than in dusty ones. Nausea, vomiting, diarrhœa, sweating, pain on urination, all lasting perhaps for several days with a slight hyperglobula and a leucocytosis of 15,000 to 19,000, were characteristic. He concludes that copper, unlike lead, is not toxic in the sense of destructiveness, but is simply irritative to the organism even to the extent of arousing the hematopoetic tissues. Immunity seemed established in about two years.

Rambousek (1913) considered all chronic industrial copper poisoning as due to admixtures of other metals.

An analysis of the air and of the dust in a Russian copper foundry was carried out by W. Jakowenko in 1926. In one cubic metre of air he found 7 to 30 mg. of dust, 1.5 to 25 mg. of which was composed of zinc oxide. He did not find any copper. Dust which had lain for long in the workshops contained 14.1 to 42.5 per cent. of zinc, 16 to 53 of zinc oxide, 0.15 to 2.19 of lead, 2.2 to 6.5 of copper, and 0.07 to 0.22 of arsenic. This expert also detected in the air the presence of carbon monoxide (0.02 to 0.29) and sulphur dioxide.

Mazzi in 1922 studied the pathology of workers engaged in manipulating pure commercial copper in the province of Sienna.

The workers engaged in the rolling mills showed lesions of the respiratory passages, digestive derangements and more or less serious attacks of colic, which he attributed chiefly to the high temperatures in the workroom, to exhaustion from the increase in body
temperature, to temperature variations and to excessive drinking (chiefly of water). In fact these affections had not been noted amongst the workers occupied in drawing copper wire by the cold process.

From pathology of coppersmiths, see article "Copper Boiler Making".

Workers engaged in polishing and scouring copper by means of emery and brushes show irritation of the respiratory mucous membrane (bronchial tubes, lungs) due to the copper and silica dust inhaled; these workers often suffer from epistaxis, hypertrophic or atrophic pharyngitis, ulceration of the nasal septum and sometimes of the turbinal bone, coughing symptoms of pneu[mco]nosis with emphysema, oligo[hem]ia due to derangement of the oxygen fixation of the blood. They easily fall victims to tubercular infection, which increases their mortality rate. Ocular affections are often met with (due to dust).

Workers engaged in cleaning and polishing copper are exposed to the action of acid fumes, in particular nitrous fumes; hence the high morbidity due to respiratory diseases and tuberculosis. Turners and fitters show the same pathological effects, though to a lesser degree on account of the small quantity of dust to which they are exposed. On the other hand, there is another group amongst them, viz. workers on the side of the arm used, and the genu valgum. Workers who prepare watch-cases for gilding and enamelling are exposed to lead poisoning.

Copper engravers are exposed to nitrous fumes when incision is effected by means of chemicals, or to dust when it is effected mechanically. In copper sulphate factories the workers are exposed to several occupational risks: handling of pyrites (dusts) and copper during drying (dust) and more especially during oxidation (chemical and mechanical action). This work is, however, generally effected in the open air or in an open shed. The most dangerous operations are certain, notably with the reaction of the sulphuric acid on the copper; preparation of hot concentrated solutions of copper sulphate; crystallisation, extraction of the salts, grinding, washing, sewing and filling of sacks. Though the exceedingly disagreeable characteristic taste of this product and especially its emetic action are of importance as factors preventing ingestion, it is nevertheless necessary to take all general measures of individual hygiene recommended by science. It is, however, a certain fact that in sulphate of copper factories no case of occupational poisoning has yet been met with.

Pinkus (1926) failed to find any cases of mercury poisoning amongst chemists and workers in a copper amalgam factory; though the metals were heated under hoods large quantities of mercury fumes were liberated in the workshop and deposited on the benches and flooring.

TOXICOLOGY

Whether copper per se is toxic or not to human beings is still virtually unestablished. The question is probably one of individual susceptibility and unusual exposure, where reported cases occur. The literature is replete with references to its relative harmlessness upon the human organism. On the other hand, certain vegetable organisms are extremely sensitive to the poisonous action of copper and its salts.

For some time there has been a certain change of opinion in this connection; it is recognised that copper exerts a certain influence in the production of poisoning, especially chronic poisoning. It is evident that small quantities of copper are swallowed daily with food. Many vegetables and shell fish contain copper, especially when, for instance, salts of copper have been used as a remedy against the formation of moulds.

Susceptibility varies very much for individuals. It is probable that the human organism gradually adapts itself to the quantity of copper taken daily. It is also possible, however, that the copper in the long run causes gastric and intestinal catarrh.

Hess and Weinstock found that as little as 2.5 mg. of copper (lactate) per litre, i.e. 2.5 parts per million, added to milk acted as a catalyst in oxidising and appreciably reducing the antiscorbutic vitamin "B", so that, for example, five out of six guinea-pigs developed scurvy within a month.

Experimentally, copper causes chronic poisoning when given in large amounts to animals (Kobert). Great care must be taken in eliminating symptoms due to traces of arsenic, lead, antimony, and other factors.

Copper has been found accumulated in all the organs of the body (Lewin), in the various excretions (many investigators), and in the bones of former copper workers, which have shown a green colour when subsequently removed from graves (Baum and Seeli-
ger). Dogs fed with copper pass it on to the suckling young (Rost, etc.), in whose livers it may be found without apparent effect. It is found in the human liver in practically all autopsies; and often in other organs, though usually in much smaller amounts.

Lewin (1900), reported by Koelsch, found that the effects of the inhalation of copper dust cause tickling in the throat, obstruction in the chest, coughing and expectoration, and that following the inhalation of fine copper or bronze dust there occurred "peculiar sensations" such as difficulty in breathing, a sense of fullness, a desire to take deeper breaths and to cough in order to move the dust from the larynx and vocal cords. To the foregoing effects, Koelsch adds irritation in the alimentary tract such as metallic taste, salivation, tickling in the throat, choking, vomiting, and abdominal pain.

Most copper salts are more or less poisonous, especially to lower forms of life, and a number of them are used as disinfectants. The irritant salts of most toxicological interest are the sulphate (blue vitriol, blue stone), the acetate (verdigris), the arsenite (Scheele's green) and the aceto-arsenite (Schweinfurth's green, Paris green).

A death from 1 oz. of copper sulphate has been reported, also a recovery. Death from ½ and also 1 oz. of copper subacetate (verdigris) has also been reported. (For the fatal doses of the arsenical preparations, see article "Arsenic").

De Witt and Sherman found that copper (chloride and sulphate) killed B. Coli and B. Typhosus, at a concentration of 1 part to 1,000,000 parts of water. Organic matter required greater concentration. All soluble copper salts, inorganic and organic (and colloidal), whether fed or injected, seemed to change into an insoluble form to be handled at the point of injection, where they caused severe ulcerations and necrosis.

Extensive experiments by Taylor, Long and Chittenden, with pathological investigations by Theobald Smith and clinic observations by Alfred Stengel, did not solve the mooted question of the influence of vegetables greened with copper salts, on the nutrition and health of man, as well as dogs and monkeys (with mean daily ingestion of copper in human subjects from 15.94 to 19.52 mg. — the whole period of observation being 120 days), proved the retention of copper by the animal body, principally in the liver, with considerable evidence of gastro-intestinal disturbances in some of the individuals in the nature of nausea and diarrhoea. However, none of the findings proved general constitutional poisoning. Drummond (1924) took up the question of coppered peas again in rat experiments extending over three months. He found copper was absorbed into the animal body, held for a time in the liver and excreted by way of the urine or of the faeces. He failed to find that such absorption led to harmful consequences — in fact, there were neither symptoms nor post-mortem findings that could be attributed to copper poisoning. Logically, since acids attack copper, acid foods should be left out of copper vessels.

Von Pethek (1924) reported a boy of two and a half years of age who died from symptoms of hemorrhagic gastro-enteritis three days after he had been treated for eczema of the scalp by an application of copper sulphate dissolved in cream. However, Cole (1924) reports an instance in a demented patient who applied a strong solution of copper sulphate to the genitals and neighbouring skin (also one year later, to the scalp) for a period of several weeks, some of the solution assuming even crystalline form due to evaporation, with the production of extensive local necrosis, but no internal symptoms of note. Subsequent healing occurred with extensive scarring.

Mallory and his co-workers found that acetate of copper added to the food of rabbits produced pigment cirrhosis of the liver in from three to twelve months, according to the size of the dose. Eventually jaundice would develop and the animals died quickly. In the early lesions, the pigment was hemofuscin granules, such granules being also found in the pancreas and other organs. Metabolic activity changed these granules in time to hemosiderin, with necrosis and regeneration of some of the parenchyma, as is the case with the deposit of hemoglobin in the tubules of the kidney. Larger doses of copper produced the same condition in rabbits. He concludes that copper must exert a hemolytic effect on the red blood corpuscles.

He found that metallic copper in fine powder taken into the body in water suspension or gelatin solution was readily dissolved, no matter how it obtained entrance through the lungs, the stomach, intravenously, or subcutaneously. When powdered metallic copper was injected into the lung
the solution formed was so strong that it caused necrosis of the tissue (see below, Pathology and Symptoms). When injected subcutaneously, the local reaction was always well marked and lime salts deposited within a few days. Furthermore, the characteristic pigments, hemofuscin and hemosiderin, were found in the liver and pancreas in two of three ex-copper workers. Skin excised during life from two workers who showed slight pigmentation gave a moderate iron-reaction (hemosiderin).

Mallory concluded that it seems perfectly evident that a certain amount of copper can be handled without danger, perhaps from 5 to 10 mg. a day, possibly more, and that "apparently the chief action of copper absorbed into the body is to cause hemolysis of the red blood corpuscles so that the hemoglobin is set free in the circulation. Part of the hemoglobin is eliminated through the kidneys, but any excess is disposed of in a changed condition as hemofuscin in the liver and later in some of the other organs".

Mills (1925) reported that Koreans are inordinately exposed to copper in the way of cooking utensils, etc.; that, in a series of almost 100 necropsies, no pigmentation of the internal organs was noticed; bronzing (of the skin) in this race might be overlooked; cirrhosis of the liver is common among them, but, with the exception of young girls (below fifteen years of age), it could be explained as due to other causes; however, with young girls this cirrhosis might be due to copper intoxication. Generally it must be admitted that special susceptibility to copper existed in the case of agricultural workers, but, with the exception of young girls (below fifteen years of age), it could be explained as due to other causes; however, with young girls this cirrhosis might be due to copper intoxication.

However that may be, the toxicity of copper even in the cases recently studied has not been so far proved, and it must be admitted that special susceptibility to copper existed in the case of the victims in question. It is interesting to recall that agricultural workers handling large quantities of solutions with a strong copper content do not show any injuries attributable to this metal. According to certain authorities, however, the theory advanced by Mallory in explanation of the pathogenesis of haemachromatosis is said to be more open to doubt.

**STATISTICS**

Copper fume poisoning (see below) was first reported in 1911 by an American metallurgical engineer, C. A. Hansen, in all of ten exposed workmen at an electric furnace; next, by Hamili in 1918 (Rhode Island), in presumably a considerable number of workmen on hot rolling of copper bars; and in 1922 by Koelsch in Germany in ten men similarly engaged on hot rolling of copper bars. These, with those reported by Mallory as chronic poisoning and the rarer indefinite allusions to various systemic affections alleged to be due to copper, constitute about all the statistics upon this subject today. The results of experimentation on both animals and man are recited above. From this situation of the paucity of our information, it behoves physicians, engineers and others connected with the copper industry in any way to report their experiences and to conduct field research into the matter where possible.

In a copper foundry in Hamburg there were reported in 1921 two cases of poisoning due to arseniuretted hydrogen affecting workers engaged in precipitating copper from solutions by means of iron. It was thought that arsenic must have been present as an impurity in the zinc covering the bars of iron. In Bavaria there were reported in 1922 cases of fever amongst workers rolling copper (copper founders' fever). In the Netherlands in 1920 a case was noted affecting a foundry worker, and in 1921 a further case affecting a worker who soldered copper and was an electric station; a third case in 1922 affected a worker who soldered copper and galvanised iron, while a fourth case took the form of nervous symptoms. Further, an enquiry effected in 1922 amongst copper founders revealed cases of copper founders' fever as affecting the majority of the workers (61) and in 1924 two cases of cataract amongst copper founders, and Roli (1923) remarked on the frequent incidence of burns amongst these workers.

Dimitrijew, of Moscow, examined 281 copper foundry workers in 1923. He was able to show that only founders suffered from the fever as well as from traumatic lesions. Generally 67 per cent. of the workers were not in good health, and 72 per cent. of these suffered from digestive troubles, respiratory and circulatory disorders, etc. The data assembled for 318 cases may be summarised thus:

- Pulmonary tuberculosis, 25 cases (9 per cent.); respiratory diseases, 44 (16 per cent.); nervous diseases (diseases of the heart and blood vessels, 51 (18 per cent.); digestive diseases, 79 (28 per cent.); diseases of the eyes, 14 (5 per cent.); diseases of the locomotor system, 9 (3 per cent.); miscellaneous, 43 (15 per cent.).

In 1924 Ikert drew attention to the frequent incidence of respiratory diseases (pneumonia, tuberculosis) amongst the miners of Mansfeld (Germany).

**PATHOLOGY AND SYMPTOMS**

Acute copper poisoning of systemic nature, due to the metal alone (short of its vaporous state), is apparently unknown. Acute symptoms due to exposure to copper dust and to copper salts, since such may be astringent and even caustic, may result in contact poisoning.
Acute symptoms associated with copper in the vaporous state appear to be the same as described for zinc fume poisoning and for fumes of other metals. Workmen manipulating hot rolls with rough copper bars, being subjected to a continuous flow of water, are exposed to a cloud containing copper and, Hamill says, arsenic fumes. The breathing of this so-called "copper chills" produces sudden attacks of "copper chills" that come on in from thirty minutes to five hours and strongly resemble malaria. According to Hamill, there is no fever, the skin assumes a light yellow colour with pinkish tips and nails, the taste is sweet, headache is severe, there is no vomiting although the blood pressure is lowered. Relapses do not occur except upon subsequent exposures. The only lasting effect is a light attack of gastro-enteritis, which may persist during the summer months and then only periodically. Hamill suggests that the headache may be due to lodgment of copper particles on the mucous membranes of the turbinate bones, to which they appear to stick like glue. Koelsch, however, found a rise in temperature even to 102.2° C. in four of his ten cases, with increased pulse to correspond, also a consistent rise in blood pressure in nine of the ten cases on the days of exposure.

The close relationship between these characteristic symptoms of metal fever and anaphylactic shock suggests that there is destruction or alteration of the delicate cell lining of the air passages, the damaged protein being absorbed, and the reaction showing in a rise of temperature. It is possible, however, that particles of the metals may be swallowed and absorbed in the gastro-intestinal canal.

Burstein, of Odessa, studied in 1925 in animals and in man the harmful effects due to ingestion and subcutaneous or endovenous injection of oxide of zinc and zinc dust with a view to ascertaining the mechanism of the action of these substances in founders' fever. He arrived at the conclusion that it was to be attributed to the action of zinc oxide. (See article "Zinc").

Ravogli has described two cases of dermatitis noted in a brass foundry. In two cases of the skin of the legs was red and oedematous, whilst the thighs were the seat of papular eczema accompanied by pruritis. After evolution of these lesions, there remained a dark brown pigmentation. There were, besides, necrotic ulcers of the thighs in one case.

The German factory inspectors' reports contained references to several cases of dermatitis of the finger ends amongst young girls engaged in soldering small brass objects.

Herxheimer has described cases of dermatitis due to the action of sulphuric acid and oil on copper wire. Amongst electricians contact with copper and brass has sometimes produced tattooing.

Clapton had reported in 1868 that dust from copper or alloys rich in copper left, in the case of sixteen workers, a greenish deposit on the teeth and gums and imparted to the hair and perspiration a greenish tint which persisted after a thorough bath; in some cases the skin may even retain a bronze appearance. While Miller (1894) did not meet with phenomena amongst 150 workers examined, Perron (1861) and Bailly (1874) admit that the teeth, to which the dust adheres, sometimes acquire a greenish colour. Biondi, Pieraccini and other authorities deny these facts, and although dentists have noted amongst copper workers a peculiar purple coloration and gingivitis accompanied by pyorrhoea and stomatitis more or less accentuated, it must be concluded that the greenish coloration referred to is probably without any pathological significance and cannot be regarded as a proof of chronic copper poisoning. Polyneuritis affecting the lower limbs (Rohrer) as well as the upper limbs (Auerbach) would appear to be an authentic symptom, though it has never been quoted by other authorities and must certainly constitute a rare symptom in view of the number of workers exposed to copper. As regards "copper colic" referred to by Ramazzini, Desbois (who is said to have met with it amongst the copper founders of Villedieu-Ies-Poëles), and Blandet (1845), its existence is not admitted by Chevalier (1847), who attributes it to lead, which is almost always present in these ores. Boys de Loury, Tardieu (1862), Galippe (1895) and present-day experts likewise do not admit the possibility of colic being caused by copper. Chronic occupational poisoning by copper is henceforth denied by all authorities, who agree with Bouchardat when he says that "lead does more harm than is feared; copper is more responsible for fear than for harm".

On the other hand, Mallory (see above) believes that the final result of long continued exposure to copper by the human being may be sclerosis of the liver and pancreas, with the consequent effects of ascites, jaundice and diabetes. He found that in nineteen such patients, four had a definite
exposure to copper in their work and that, while in less than two-thirds of the cases, no evident source of chronic copper poisoning was apparent, collateral investigation showed that people in the first case must be constantly exposed to the danger of copper ingestion. He concludes: "Evidence is slowly but steadily accumulating in favour of the view that chronic poisoning with copper causes the symptom complex known under the different names of hemosiderosis, bronzed diabetes and pigment cirrhosis."

Finally, Coppez (1927) reports two cases of ocular chalcosis observed, that is to say, impregnation of the ocular tissues by salts of copper. The first affected a child who was the victim of the explosion of a detonator, the second was of occupational origin and affected a worker twenty-four years after his eye had been wounded by a splinter of copper. There was decoloration of the iris (greenish blue tinge), choroiditis disseminated in the form of pigmentated stains and bluish exudative spots: the upper visual field was destroyed and the sight coefficient was 0.5.

**Demonstration**

Compounds of copper impart a bright green coloration to the flame of a Bunsen burner. Tanner, revised by Trumper (1925), summarises as follows:

Solutions of copper salts are blue or green. The metal may be thus identified:

1. A polished knife or needle introduced into the solution slightly acidulated is soon covered with a bright red coating of copper.
2. Ammonium hydroxide produces with a salt of copper a bluish precipitate, readily soluble in excess of ammonia, and then forming a splendiferous blue solution.
3. Potassium ferrocyanide gives a claret-coloured gelatinous precipitate, if the copper be abundant, otherwise the deposit is light brown. (Delicacy, one part of copper in 500,000 of water.)
4. Hydrogen sulphide yields a deep-brown precipitate.
5. A few drops of the copper solution are to be placed on platinum foil, and slightly acidulated; on touching the foil, through the solution, with a strip of zinc, metallic copper is deposited on the platinum. Supplee and Bellis with Hess found the ethyl-xanthate test the most satisfactory "milk, urine, etc.". Small amounts of copper react with potassium-ethyl-xanthate to produce a yellow colour, which colour is in direct ratio to the amount of copper present. Other elements such as iron, lead, nickel, cobalt, zinc and manganese do not interfere. The delicacy, for copper in milk, was found to be 0.005 mg. to 100 cc.

The following method was recently proposed by J. Aloy and A. Valdique. Dissolve 0.20 grm. of hydroquinone in 100 cc. of pure distilled water, add 20 drops of a centimolar solution of HCl; place 10 cc. of this reagent in a test tube and heat the tube for half a minute in boiling water; add one or two drops on the solution to be examined, which should be neither alkaline nor very acid.

In the case of the presence of salts of copper there is formed a blue coloration which is rapidly augmented. This reaction can be used for measuring copper colorimetrically.

**Preventive Measures**

Without question, workers should be removed from exposure to fine copper dust, the dust and solutions of copper salts, and from the inhaling of the fumes of copper when the metal is heated at high temperatures. The measures against dust, heat, poisons, fatigue and accidents taken in mining and in smelting follow those well known for safety in the derivation of metals. Harrington concludes that the outstanding remedy for the bad situation in mines is education, which may be said to apply to most of the other situations in the copper industry for there is sufficient knowledge and technical skill apparently already at hand.

**Legislation**

Work in mines and foundries is in general regulated as for all metals and all mines. Young persons under sixteen are excluded from the manufacture of copper compounds and from scorching by means of nitric acid (free liberation of nitrous fumes), in Belgium; under eighteen years in France from vitrification of copper compounds (free liberation of dust) and from scorching of copper (free liberation of acid fumes); boys under sixteen and women under eighteen in Canada (Quebec) from cleaning white copper by means of acids; women under twenty-one from cleaning and polishing of copper (liberation of dusts and acid fumes) in Spain; young persons under eighteen years of age from work on white copper liberation of dust, etc. in the Netherlands.

Women are absolutely excluded from the manufacture, grinding and treating with acids compounds of copper in Argentina.

Special legislation existed in Russia in regard to hygiene and accident prevention in copper foundries and factories 1909 and 1910; it has been again issued by the Soviet Government. In Great Britain a Welfare Order of 1917, No. 1927, is devoted to conditions in copper foundries.
In the Netherlands foundry workers' fever in yellow copper foundries is subject to compulsory notification and similarly poisoning by copper in the State of Missouri (U.S.A.). It is compensated as an occupational disease in Argentina, Brazil, Chile and in Queensland. Copper itch is also compensated in the latter State when affecting copper miners.

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**Copper Boiler Making**

French: **Chaudronnerie en cuivre.** — German: **Kupferschmiederei.** — Italian: **Cottruzione di caldaie in rame.** — Spanish: **Fabrica de calderas de cobre.**

The use of copper on a large scale for making boilers, cisterns, tanks, large apparatus for distilleries, breweries and sugar refineries, installations of pipes and worms, as well as copper work for smaller objects, such as the manufacture of copper or brass cooking and household utensils and in ornamental copper work, involves almost exactly the same processes.

For large-scale work the processes are similar to those of iron boiler making: marking out the lines for cutting and piercing of holes, drilling, embossing the holes for the rivets, chamferring or trimming the edges of the plates; heating the metal sheets in reverberatory furnaces; bending by rolling; beating out; assembling the pieces; sliding down; hammering; welding by heat, by hammer, by hydraulic press, or autogenously.

Work on small copper articles was formerly done, and is still quite often done, by hand with a hammer; but the power-press and the lathe are coming more and more into vogue for stamping and riveting. Shaping out is done by hammer or wooden mallet, while surface smoothing is done with a hammer; soldering may be done with tin or brazing with strong solder. Thus it is seen that this industry is characteristic by hammer work, whether by hand or pneumatic tool, and by brazing.

Brazing, or strong soldering, is carried out by means of copper, silver, or brass, or an alloy melting at a high temperature. After adjustment the pieces to be soldered are bound with steel wire, they are then heated in a coke-oven or gas furnace until the copper or alloy melts and runs into the joints, forming a weld on solidifying. Autogenous welding is also used (see article "Welding (Autogenous)").

Other operations may also be mentioned, such as, for instance, the cleaning or detartrasing of boilers: prickling with a pointed hammer or a grooving tool the manufacture of metal articles in repoussé (repoussé is embossed or relief work wrought on a sheet of copper placed over a resistant mastic or on a hollow wooden mould); rolling thin sheets for imitation jewellery, for making plates used for plating metals or for harness, and for copper work on buildings by casting or stamping (see also articles "Jewellery Industry", "Copper").

Coppersmith's work is often carried on, when it is a case of large pieces of work, either in the open air or under roofing.

**Sources of Danger**

The sources of danger for coppersmiths may be enumerated as follows: heat, deafening noise, dust, the use of hammers (either hand or pneumatic), exhaustion, callosities of the hands, danger of burns, illness from cold, contusions, irritation of the mucous membranes of the eyes, nose, or upper respiratory passages, poisoning by lead or oxalic acid in the case of polishers of utensils, nitrous fumes, arsenuiretted hydrogen, carbon monoxide, and sulphur dioxide. There must also be borne in mind the effect of bad posture due to long periods of work spent either standing, bent forward, on the knees, or lying down, while the body is being shaken by heavy tools, hammers, and other appliances worked by compressed air.

**Pathology**

According to investigations reported by Mazzi in 1921 regarding a number of coppersmiths in the province of Sienna, and others by Swiss experts during 1923-1926, the occupational pathology of this class of workman can be summed up as follows: disorders of
hearing in particular affect those who have worked for a long time as boiler makers. Holt found such trouble in 35 per cent. of those examined; Barr in 91 per cent.; Habermann found them in 31 boiler makers whom he examined, with vertigo in advanced cases. Opitz, in his statistics of recruits noted that 4.6 per cent. of boiler makers had affections of hearing, against 2.4 per cent., among locksmiths and 2.3 per cent. for all occupations.

Deafness among boiler makers shows itself by a diminution, more or less pronounced, in the hearing for the perception of natural or whispered speech; by a diminution in the conduction of sounds from a tuning-fork reaching the ear through air or through bone; and by subjective disorders, such as buzzing, vertigo, and loss of equilibrium.

This lesion is connected with phenomena of labyrinthine sclerosis, which comes on slowly in the course of a long period at this occupation. Sound waves of high pitch, following one another for a long period at very brief intervals, are transmitted by the middle ear and affect the internal labyrinth, the seat of the auditory function.

Katin-Jarzew in 1925 recorded that, after a certain time, it is possible to distinguish in a workshop two alternative sounds: one low and loud which is comparatively bearable, and another sharp, piercing, in the hearing for the latter which hurts the ear. In addition to this injurious influence of noise, the shaking of the body must be noted, caused by the pneumatic hammer.

Trambitzi in 1923 carried out an enquiry among 431 out of 540 workmen employed in the locomotive works of Kharkow. Among these boiler makers there were skilled workmen and ordinary labourers. He divided them into two categories, 253 continually exposed to the noise, and 180 accidentally exposed. In the first category 143, or 56.5 per cent., complained of giddiness, and in the second category 107, or 59 per cent. These workmen were obliged to interrupt their work for short periods on account of this painful sensation of giddiness. The noise in the workshop was so great that to make oneself heard it was necessary to shout in the ears.

As regards buzzing in the ears, Trambitzi received 205 complaints, 81.6 per cent., in the first category, and 132, 72.9 per cent., in the second. This condition, which the workman does not notice whilst at work, becomes very marked at home and does not cease day or night. It is very troublesome, makes the head heavy, and interferes with thinking.

Examination of the hearing, with the tuning fork and whispered voice, establishes that the workmen suffer from deafness, a disease of occupational origin, the frequency of which is shown by the following table, arranged according to length of service:

<table>
<thead>
<tr>
<th></th>
<th>18 months to 3 years</th>
<th>4-5 years</th>
<th>6-10 years</th>
<th>11-20 years</th>
<th>21-30 years</th>
<th>30 years and over</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boilers makers using the hand hammer</td>
<td>--</td>
<td>66.6</td>
<td>75.0</td>
<td>80.0</td>
<td>87.3</td>
<td>100.0</td>
</tr>
<tr>
<td>Boilers makers using the pneumatic hammer</td>
<td>43.3</td>
<td>40.0</td>
<td>56.7</td>
<td>77.4</td>
<td>83.3</td>
<td>100.0</td>
</tr>
</tbody>
</table>

In 1926, 464 boiler makers aged from nineteen to sixty years working with pneumatic tools were subjected to a medical examination at the Institute for the Study of Occupational Diseases at Leningrad: 178 boiler makers had less than ten years' service, 152 had from ten to twenty years, and 134 had twenty years' or more.

Only a fifth had worked permanently in boiler works; the others had changed their occupation several times, some five or six times. These occupations had been very varied and often had no connection with noise.

The enquiry confirmed the fact that the characteristic disease of boiler makers is deafness. It has been found, however, that disease of the middle ear constitutes in some degree a protection against this deafness, so that there is no ground for refusing candidates affected with otitis media. The very common use of plugs of cotton wool has no effect on the development of the deafness. Out of 464 boiler makers examined, 65 had protected themselves by means of plugs, but without result. That can be explained by the fact that cotton wool does not hermetically close the auditory meatus, nor does it prevent the entrance of sound waves. Besides, if the wool could hermetically close the meatus, it might cause...
pathological conditions of the external ear.

Interruption of work has no effect on the development of the deafness which, with similar lengths of service, attacks most rapidly those workmen of mature age.

The spirometric and anthropometric results of the Russian enquiry show that boiler makers are selected from strong individuals with powers of resistance. The teeth are usually good and resistant to caries, but as the result of the bad habit of clenching the teeth, they lose their polish and the roots become bared. As a matter of fact the proportion of teeth with bare and unpolished roots is among boiler makers 3 to 3½ times greater than in other occupations.

A rather unusual amount of damage to the conjunctiva and cornea occurs, due to wounds, although not serious ones, caused by sharp particles of metal. But the damage is more serious and the scars are more marked if the workmen are old. By means of a screen placed at the height of the eyes about 15,000 particles of metal were caught in ten minutes.

As regards the locomotive system a considerable percentage of workmen are found with an abnormal mobility of the vertebral column, this being characteristic of this occupation, for boiler makers are obliged to work in the most varied positions.

Flatfoot has been found in 16 per cent. of workers; chronic articular rheumatism in 1.5 per cent.

The Russian enquiry has called attention to a certain degree of hypotony of the muscles of the hands, especially of the right, as well as an increase in their mechanical excitability, due apparently to prolonged muscular exhaustion.

Cases of crepitant teno-synovitis of the wrist have been described. Further, in all occupations a difference in the two hands has been noted, but it is particularly so in the case of boiler makers.

Bradycardia, with a pulse below 60 per minute, has been found fairly frequently, group A = 38 per cent.; group B = 41 per cent.; group C = 52 per cent. (standardised for age), it is probably an occupational manifestation. Boiler makers present more frequently than any other class of workmen a regular pulse after exertion. In 23 per cent. of the cases bradycardia is accompanied by marked hypotony (rarer in group C) of the walls of the vessels.

Varicose conditions have been found in 6.5 per cent. of the cases: however, this percentage is very low when one considers that boiler makers work standing. In 11 cases the veins of the forearm were affected.

As regards the respiratory apparatus, active tuberculosis has only been suspected in 1.6 per cent. of the workmen examined, latent tuberculosis in 23 per cent., and pulmonary emphysema in 2.6 per cent.

A condition of irritation is to be found on the mucous membranes of the pharynx, bronchi, caused by dust, made up chiefly of copper particles which become detached during hammering; they are composed of cuprous and cupric oxides which form during the hammering of copper, either hot or cold. Noise is also caused by cutting out of coal and soot, and by radiant heat.

Digestive trouble is favoured by sitting at work and bending forward, by gases given off during various processes, by the confined atmosphere of the workplaces, by getting chilled, and particularly by indulging in cold drinks.

One might expect to find tremor of the hands resulting from the vibration of the tools; on the contrary, it has been observed that boiler makers have very much steadier hands than workmen of other classes. Likewise, very few cases of neurasthenia have been observed, and in these alcoholism plays a more important part than the occupation. Then again it might be supposed that noise would be a factor in the aetiology of this disease, and logically one would have expected a smaller percentage of neurasthenics among persons affected with deafness; however, here the contrary is the case.

Lesions of the peripheral nervous system seem to be more closely connected with the occupation (6 per cent. of workmen). Neuritis and neuralgia of the extremities have been attributed in a great number of cases to traumaism and in others to over strain. The right arm and left leg are the most affected, probably because they bear the greater part of the exertion. In serious cases workmen have been obliged to give up their trade.

Hernias have been found to affect a fifth of the workmen examined.

Characteristic callosities occur on the hands; they are true hyperkeratoses, which are due in the case of the right hand to grasping the hammer, and in the case of the left to holding the object being hammered. These callosities are
generally situated on the fourth and fifth fingers, especially on the hand.

Workmen occupied in tinning copper utensils, generally the coppersmiths themselves, present also the same lesions of the mucous membranes of the respiratory passages, due to the irritant action of acid or alkaline fumes, of hydrochloric acid or ammonia, or of fumes of zinc oxide. Sometimes the trouble is due to impurities, of which the most important are lead and arsenic, contained in the ammonia salt and tin. This is why Mazzi was able to discover among these workmen some cases of slight lead poisoning.

It is advisable to exclude youths from these workshops, and, in particular, workmen suffering from affections of the respiratory passages.

**Hygiene**

Measures of hygiene must deal with the elimination of gases, fumes and dust, but, more than all, with the utilisation of materials and the adoption of buildings constructed in such a way as to avoid resonance and diminish noise as far as possible. It is advisable to isolate different parts of machines, to cover boilers during work with layers of india-rubber, or other material which is a bad conductor of sound. The floor and the stage of scaffolds where workmen stand must be firm.

The workplaces must be spacious and well ventilated. Tinning processes must be carried on under a hood with an adequate exhaust. The wearing of masks furnished with lunettes is advisable. The filtering material of the mask must be moistened with pure water, in order to fix the acid and alkaline fumes of hydrochloric acid and ammonia, which on contact by mutual reaction give rise to ammonium chloride, which dissolves in the moisture of the filtering material.

As a measure of individual protection the wearing of felt is recommended in the form of shoes, gloves, and knee-caps when the workman works on his knees. Workmen should also be advised to wear plugs of cotton wool in the ears during the whole period of work. Medical examination should take place on commencing work, and periodical examination should be held also. Workmen who report diminution in hearing must be drafted to other work.

**Legislation**

See article "Copper". In addition, cases of inflammation of the joints, the skin and the subcutaneous cellular tissue found among boiler makers are compulsorily notifiable in the Netherlands.

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**Coral**

French: Corail. — German: Koralle. — Italian and Spanish: Corallo.

Coral is composed of the calcareous shell of myriads of minute stationary polyps (product of the coelenterata). The shell is in tree form and is inhabited by the polyps as a protection when surrounding conditions are unfavourable to their development.

Coral is generally found at a depth varying between 50 and 200 metres. Coral fishing has been carried on from time immemorial. It is effected by divers, who loosen the coral by means of a suitable tool. There has also been invented an instrument which permits of detaching the coral from the surface without the help of divers.

Coral is at the present time still worked by hand by art workers, either in laboratories or in their homes, according to the processes in question. Thus, for example, cutting is usually done in factories, piercing is a home industry, and shaping of the beads is done both at home and in factories.

Home work is carried out by women who only use very simple and primitive tools (Naples). When the industry was in a flourishing condition, nightwork was very general.

The coral is first sorted and classified in accordance with the length of the branches, the colour and the state of preservation.

The processes of manufacture comprise the preparation of a commercial,
or smooth, product, and of an artistic product involving incision. The preparation of each of these products covers a series of distinct operations, entrusted to special categories of workers. This fact explains why each of these categories develops characteristic stigmata.

Commercial operations comprise sorting the crude coral, cutting, sifting, piercing, cleaving, shaping, polishing and matching.

Artistic operations: comprise cutting, rough shaping, setting, incision and finishing.

In the course of commercial operations, the worker has to mark the place where the branch is to be cut. For this purpose he uses a heavy file, which is likewise used for freeing the coral from all incrustations. He makes an incision at the mark in question with a steel blade, and cuts off the branch by means of long nippers about 0.60 metres in length, which he manipulates horizontally, supporting them on his hip.

The pieces of coral obtained are sorted out according to their length by means of metallic sieves. Piercing is effected by means of an arc-shaped bit, held in the left hand and worked with the right. A jet of water is directed on to the coral with a view to preventing heating of the point and reducing the dust produced in the course of the piercing operation.

The "beads" obtained are rounded by hand, by means of a file, or by means of a grindstone when large.

Hand polishing is effected by friction, applied to a cloth sack containing the beads and pumice-stone, under a jet of water. Emery grindstones are also used, but less frequently. The beads are then dried and matched.

In the case of artistic work, the branch is severed by means of a circular saw without teeth. This process gives rise to a smell resembling that of burnt horn. The pieces are reduced in size by means of instruments similar to those used for grinding. The piece of coral is thereafter fixed on a block of wood by means of pitch and is subjected to incision by application of an engraving tool. The finishing is entrusted to a polisher, who uses a paste formed of pumice-stone and oil. This delicate process, which is extremely difficult and requires patience, is followed by cleaning with sulphuric acid applied by small brushes, and then washing in soapy water and drying.

Mechanical incision, as suggested by the Americans, is hardly known at Torre del Greco (Naples), where specialists in the work prefer to give proof of their manual dexterity.

The following varieties are used: red coral coming from Zanzibar; pale coral or rose coral of American origin. It should be added that workshops where cameos are manufactured also employ mother-of-pearl (especially waste mother-of-pearl coming from button factories), tortoiseshell, ivory, etc.

In certain workshops all the work is carried on in a wet state, whilst in others all the processes are done dry (manufacture of "beads"). The dust, however, does not remain suspended in the atmosphere, because it is not very light and is not produced with sufficient force to carry it to a distance. On the other hand, workshops in which mother-of-pearl and coral are ground on emery wheels are excessively dusty.

Coppa (1922) studied the health and sanitary conditions of coral workers at Torre del Greco (Naples), and examined seventy workers, in regard to whom he reported that the work in question is the cause of a high sickness incidence.

Fifty-seven coral workers, engaged in the manufacture of the commercial product, presented an incidence of 34.8 per cent. of diseases of the locomotory system, amongst which the most important were myalgia, lumbago, cramp due to a bad posture during work; an incidence of 18.8 per cent. for respiratory diseases (cough, bronchitis, dysphonia, etc.), caused by the quantity rather than the quality of the dust inhaled; a rate of 15.7 per cent. for digestive diseases (constipation, bad digestion, etc.), of 15.7 per cent. for nervous diseases, and of 16 per cent. for various diseases. There was reported a case of atrophy and one of sclerosis, neither serious but sufficiently marked for the lower turbinal bone as well as loss of sensibility in the nasal mucous membrane. As regards the stigmata, Coppa has described several calllosities of the hand, situated on the right thumb (very developed amongst the bead makers who use the file) and on the left hand (amongst the workers who cut the branches, the polishers, and particularly the bead makers. These workers are obliged to engage in work which is excessively tiring for the right arm (use of the file), whilst workers engaged in reducing the pieces in size are much less subject to fatigue.

In the second category of workers (artistic work), Coppa met with a sickness rate of 33 per cent. for various diseases, of 23.18 per cent. for eye diseases (due to close delicate work — at 15 to 20 centimetres), 21.73 for nervous diseases, 11.59 for digestive diseases and 10.14 for respiratory diseases.
Lesions due to the mechanical action of branches of coral on the skin have been reported as occurring on the hands and feet of coral fishers. Such lesions have a tendency to develop into ulcers, which readily become infected.

No special data are available in regard to hygienic precautions to be adopted, for they are analogous to those for workers exposed to risk during manipulation of horn, bones and mother-of-pearl, etc. Coppa, in his study of the question, has dealt with the special conditions of the industry at Torre del Greco, and suggests the most appropriate measures to be adopted. There are no legislative measures dealing with this work.

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**Cork and Linoleum Industry**


**TECHNICAL DATA**

Cork constitutes a part of the bark of the cork oak and certain of its varieties, the cultivation of which is an important industry in various countries (Spain, France, Italy, Portugal, Algeria, Morocco, Tunisia). Cork of good quality is a uniform, compact substance, formed of fawn-coloured layers, the surface of which is pitted with small holes and pinpoints. Cork of second quality is more homogeneous, more compact, and less pitted than the first production substance: but the third product is still better. In commerce, three classes of cork are distinguished: grey cork, obtained directly from the plant; scraped cork, which has been deprived of its bark by scraping off of the lignified surface; commercial cork, ready for use.

When the tree has attained an age of sixteen to twenty years, a first harvest of the cork is gathered at the appropriate season (June to July), care being taken not to injure the internal layer, which forms the inner bark or bast (barking or peeling). The cork extracted has been deprived of its bark, as long as the bast has been left intact, grows a new yield of homogeneous, elastic, and slightly porous tissue, slightly pitted, and showing, in cross section, various layers. This is the true commercial cork (second cork, female cork, reproduction cork). Second cork grows with a certain rapidity during the three or four first years, then more slowly, and towards the fourth year it attains its maximum thickness. It is generally harvested between the eighth and twelfth year. Then the subsequent harvests are repeated at similar intervals.

Harvesting is effected by making suitable incisions in the bark in the form of circular cuts, and joining these by longitudinal cuts. The bands of cork are placed in even heaps, which are allowed to dry for one month, and then submitted to various operations, the object of which is to give the cork a more acceptable form and aspect for commerce and to facilitate storing and transport: scraping of the superficial lignified part, scalding, cutting, paring and polishing.

**Making of Corks (Bottle Stoppers)**

After grading the pieces of cork according to quality and thickness, they are cut up into cubes or into parallelepiped pieces, according to the product to be manufactured. The pieces obtained are sometimes placed directly on the market for the manufacture of corks, but more often they first undergo the following operations:

*Cutting.*— Cutting of the cubes into cylinders or cone-shaped pieces may be done by hand or by machine. The hand work consists in cutting out, with the aid of a very sharp knife, the edges of the pieces of cork, with a view to giving them a definite form. This operation is showing an increasing tendency to disappear, but is still done for very large-sized corks. Neither trying nor dangerous, this work however requires great dexterity in order to obtain regularity and uniformity.

In machine manufacture there may be used a lathe with a cutting blade or an emery wheel revolving at high speed, or a tray having two concentric rings of glass paper glued to it, that at the periphery being generally of much finer grain. The cork is held against it to round off the edges and polish the sides and base of the article, which is held in position by a special spring clip. Corks, when finished, are sorted according to quality and size, either by hand or by machine.

After washing in acidulated water sulphuric or oxalic acid, or even
sulphur dioxide) the corks are dried generally in the shade. They thus acquire a yellowish rose colour and a velvet surface. They are then marked (numeros of manufacturer, name of customers) either by burning or by the use of a special ink.

Manufacture of glued corks.— The so-called glued corks are corks in two pieces, which are joined by gluing. This permits of the utilisation of thin cork of inferior quality. The cork, on arrival, is cut into pieces, and where necessary into small thin plates, either by a knife or by means of a band saw. These small plates are then dressed on one side (internal face) with a view to removing inequalities of the bark by means of a wheel, as in the preceding process. The other side is then sawed, to give the requisite thickness, and to obtain a surface at once flat and rugged, with a view to facilitating perfect adhesion by gluing. The small plates after having been carefully sorted (same colour, same resistance), are placed side by side on large trellis work trays and then carried to a heated drying machine, where gluing takes place. The two surfaces are glued together, and the two pieces submitted to pressure in a screw press or similar machine. The corks are then turned on a wheel and submitted to the same operations referred to in the foregoing description of technical processes.

Manipulation of old corks.— Old corks are often collected and submitted to renewal processes. Sorting takes place with a view to freeing them from various products which may still adhere to them, such as hooks, metallic capsules, debris from tin wire, etc. There follows immersion in boiling water to cause swelling of the corks to their former size. They are then cleaned and rendered aseptic, after bleaching and re-sorting to separate out those corks which are fit for further use. They are finally submitted to cutting.

Manufacture of Linoleum

Linoleum represents one of the modern adaptations of waste from the cork industry. It consists of a resistant, impermeable hygienic covering, used for floors, bathroom walls, laboratories, dining rooms, etc. Linoleum is essentially composed of oxidised linseed oil (principal element), to which is added elements of support, vegetable gum, Kauri gum, rosin, and powdered cork, the whole being fixed with a coarsely woven framework of hemp or jute. There has at times been used as a substitute for cork 1, and in the place of linseed oil, residues from distillation of palm oil or of cotton. The manufacture of linoleum is lengthy, though recent processes have somewhat shortened it. It comprises the following operations.

Oxidation of the linseed oil by exposure to air or by addition of oxidising substances (minimum, litharge, acetate of lead, oxide of zinc, manganese dioxide). After cooling, the oil is spread on bands of cloth and dried. This operation is repeated for eight to twelve hours during several months, in order to obtain a layer of linseed oil two centimetres thick.

In the _mixed oxidation_ process the method followed is a combination of heat (35° C.) and the application of oil in fine spray. In the _polymerisation_ process the oil is exposed to a very high temperature (325° C.) for about eight hours, air being injected into the furnaces, which are open or provided with hoods.

Whatever be the processes employed, the finished product obtained consists in linoxin, a brown, elastic, neutral mass, insoluble in ether, which on oxidising furnishes a peroxidised oil.

The powdered cork required is obtained from waste from the manufacture of corks and cork objects. After having passed through a magnetic separator in order to remove all traces of free iron, the cork is crushed into pieces of the size of a nut, and sent to pulverising machines. It is assembled in a cyclone machine and passed to crushers again until the powder contains a subdivision analogous to that of flour. It is then bolted and sieved.

Linoxin, after malaxation, is mixed in a steam-heated stove with the elements of support and pigments (red oxides or permanent lakes, ultramarine blue, chrome green and Brunswick green, white lead and lithopone, chrome yellow, vegetable black, etc.). The cement thus obtained undergoes malaxation and heating, and is again passed through malaxation apparatus. The mass is sometimes rendered more plastic, and less brittle, by the use of petroleum and turpentine.

The mass, having again been heated, is subsequently applied to a canvas base (made of jute; see article “Jute”), the back of which has been covered

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1 A substitute for cork in this industry is cupreine (carbène), a highly condensed product produced by the action of arenes on hot copper. It can be vulcanised by sulphur chloride or sulphur. It is also used as an insulating material, as an acid resistant, in the electric industry, etc.
with a layer of thick paint, generally red, with anoxide of iron basis. After drying, the canvas passes over tray presses or into vertical calenders with steam heated cylinders, in which the linoleum paste is evenly distributed over the canvas. There follow the operations of finishing and cooling.

After leaving the calenders, the linoleum arrives in a special chamber, and cooling. Further operations are required. If the temperature of 40 to 60° C. is reached, the linoleum is removed for another treatment. But the linoleum is not yet suitable for use. Here it will be given a coating of Japanese lacquer. In course of this treatment, the surface of the finished product is not altered, but its surface quality is increased. The coating is merely superficial. The printing is done in oil colours, consisting of a mixture of linseed oil and Spanish white or lithopone (as a basis), to which have been added pigments and drying media. The preparation of the paint involves very fine grinding and a thorough mixing of the different constituents in various grinding and mixing machines.

The printing of the designs is generally effected by means of wooden or metal moulds, either by hand or by printing machines. When this has taken place, the surface is generally given a coating of Japanese lacquer. In the case of intalined linoleum the decoration is effected throughout the whole thickness of the material. The technique followed consists in the application of very ingenious machines, which apply under pressure and at high temperature the granulated mixture of the various colours by the use of small stamps or suitable perforations. In this type of linoleum, as well as in the kind known as granite linoleum, the design does not fade with use. The mass applied to the supporting canvas passes through heated cylinders, which exert pressure in fixing it. The linoleum, in the case of these articles, is such that there can be moulded on to it designs in very pronounced relief in imitation of sculptured wood (sides of wagons, interiors of houses, ships, etc.).

Cork carpets are similar to linoleum, but the grain of the cork is coarser in the case of these.

USES OF CORK

Besides the manufacture of corks just referred to, cork is utilised in numerous industries, particularly for the manufacture of cork objects, hatbands, soles for shoes, lifebuoys, corks and floats for nets, lifebelts, joints, discs, lining for boilers and steam pipes, heat insulating coverings, for tanning, in rustic constructions, ferteries, etc. Powdered cork is again used in the manufacture of insulating products, for packing fruit, and in the manufacture of agglomerated cork, and of cork black.

Agglomerated or artificial cork ("phellosine", "suberin") is obtained by boiling powdered cork with water. The heated mass is submitted to a pressure of 200 to 300 atmosphere, at a temperature of 250° to 300° C., sometimes with the addition of agglutinating substances (linseed oil, mucilage, lime, clay, chloride of manganese, albumen, resin, collodion, pitch, etc.). This product, which is harder than natural cork, serves for the manufacture of squares for covering floors and walls of rooms, for the refrigerating wagons and the construction of foundations for stamping presses, etc. Objects made of artificial cork are obtained by moulding under pressure and baking in a furnace.

Sources of Risk

1. In course of harvesting of cork, injuries to which workers are liable have no specific character, and consist principally in accidents and exposure to inclement weather conditions (see article "Agricultural Labourers").

2. In course of the manufacture of corks, the principal source of danger is constituted by the abundant liberation of dusts, as in general for the whole of the cork industry. As an example, it may be recalled that in the making of champagne corks each cube of cork handled weighs about 10 grm., and the finished cork about 6 to 7 grm., with a result that about 35 per cent. of the raw material is, in the course of manipulation, transformed into dust. The dust is thin, light, and penetrating, and, in workrooms with insufficient ventilation, is deposited everywhere — on the machines, on the workers, and on their clothes, which rapidly become covered with it.

In addition to the harmful physical action with which this dust and the impurities it contains may exert, cork dust suspended in the atmosphere may sometimes give rise to fire and explosion (see article "Dust, Fumes, and Smoke").

The manufacture of glued corks presents, besides the risks above referred to, certain others connected with the
use of glues, and varying according to
the products and solvents utilised. A
French factory inspector in 1906 re-
ported cases of injury due to an ether
glue, which made it necessary to install
special hygienic apparatus (localised
exhaust).

3. In the manufacture of linoleum,
the principal danger met with is that
of dust during pulverisation of the
cork. It should be mentioned that risks
from explosion are particularly great
when the operations are not effected in
closed apparatus, and explosions have
been known to occur also during grind-
ing and the successive mixing opera-
tions. Trituration and bolting of cork
are processes which possess the great
disadvantage of being extremely noisy.

The heating of linseed oil implies not
only exposure to excessive heat, but
also inhalation of acrolein and other
harmful products. The addition of
resin with hot linseed oil involves
liberation of volatile substances, and
the ethereal oil produced is considered
by experts as having an unhealthy
effect on the system.

The manufacture of linoleum may
also involve exposure to other causes
of risk, such as, for instance, lead
compounds, used as drying media
added to the boiling oil in the manu-
facture of peroxidised linseed oil or in
the compounds used in colour printing).
The latter may contain pigments with
arsenic, mercury, or sometimes
manganese basis. Among the products
used in the course of various opera-
tions should be recalled benzene,
xylene, methyl alcohol, amyl acetate,
sulphuric acid, petrol spirit, tur-
pentine, and pitch.

Finally, causes of injury may be rep-
resented by exposure to sudden varia-
tions of temperature and to humidity.

STATISTICS

The statistics available relative to in-
juries reported in the cork industry are
very few in number: In the Netherlands
in 1920 two cases of nervous troubles were
met with in a linoleum factory where, every
second day, there were dissolved 75 kg.
of paraffin in 250 litres of xylene, with
the object of giving a smooth appearance
to linoleum, which was made to slide
under a roller impregnated with this solu-
tion. In 1930 in Great Britain, a case of
conjunctivitis was reported, affecting a
worker occupied in oxidising linseed oil.

PATHOLOGY

There are frequently noted cases of
inflammation of the mucous membrane
of the eye, the nose and the upper res-
piratory passages, due to dust. The
lack of morbidity statistics, however,
renders it difficult to estimate the
exact role played by dust in the etiology
of these troubles.

The ethereal oils liberated when the
resin is mixed with the linseed oil give
rise to headaches, sickness, and some-
times a state of complete stupor.

The latter may contain pigments with
an arsenic, mercury, or sometimes
manganese basis. Among the products
used in the course of various opera-
tions should be recalled benzene,
xylene, methyl alcohol, amyl acetate,
sulphuric acid, petrol spirit, tur-
pentine, and pitch.

Finally, causes of injury may be rep-
resented by exposure to sudden varia-
tions of temperature and to humidity.

HYGIENE

The following measures are recom-
manded: construction of workshops,
and particularly those in which cork is
manipulated, of incombustible ma-
terials. Where this is not possible, all
the woodwork should receive a coat-
ing of plaster. Walls should be coated
with smooth paint, in order to prevent
dust adhesion, and frequently washed
with plenty of water. The workshop
should be provided with swing doors
opening outwards, and the requisite
additional precautions against fire
should be applied. The workshops
should be well ventilated.

Lighting should, as far as possible,
be provided by natural daylight, and,
where this is not the case, by lamps
placed outside, or separated by fixed
glass, or by closed electric lamps, with
a double cover, the circuit breaker
being placed outside the workshop.

For heating, steam or hot water is to
be recommended. Where this is impos-
sible, furnaces and hearths should be
outside the workshop. Stoves should be
heated by steam, and not by hot air.

The operations of breaking, cutting
up, pulverising and bolting cork should
be effected in closed apparatus. All
the machine tools used in shaping the
cork should be provided with local
exhaust devices, envelopes and hoods,
which entirely surround the machine,
with the exception of the part strictly
necessary for manipulation.
On account of the lightness of the dust, apparatus so far adopted for dust recovery (cyclone machines) have not given satisfactory results, as they at times allow part of the dust to escape through the vent hole. It is preferable, therefore, to apply apparatus for humidifying the dust, which is thereafter easily collected.

As a defence against toxic fumes and products, similar local exhaust devices should be adopted. Stoves and boilers should be provided with hoods. The harmful fumes and smoke should be directed towards hearths in which they can be burnt, or towards very high chimneys.

Workmen should be forbidden to enter the stoves before renewal of the air, and should be obliged to use suitable lamps for lighting stoves. Explosions of cork dust being frequently due to the fact that particles of iron produce sparks when the material is passing over emery wheels, it is advisable to have the cork dust introduced into a magnetic separator prior to this operation.

It is essential that stores of raw materials (benzene, spirits, oils, varnishes) should be isolated and kept at a distance from the factory hearths. A quantity of sand should be available in case of fire.

Amongst the measures of individual hygiene to be recommended, the following are of importance: provision of working clothes, headgear for women (protection of the hair), and, where necessary, respiratory masks and glasses.

Legislation

Legislation is similar to that for those industries in which there is exposure to vegetable dusts. In France, young boys under eighteen are excluded from trituration of cork in factories which have not adopted the requisite measures for dust elimination.

Cotton Industry


Cotton is the lint attached to the seeds of the plant belonging to the natural order of Malvaceae or mallow, forty to fifty varieties of which are known. Besides Gossypium Arboreum, which is not grown commercially, there is used chiefly Gossypium Herbaceum, which includes most of the Indian, Chinese, and short stapled Egyptian cottons; Gossypium Barbadense, which includes the long stapled Sea Island (South Carolina), Egyptian and Peruvian varieties, the seeds of which are black and without undergrowth; and Gossypium Hirsutum, a hairy plant generally, the seeds having a thick downy undergrowth, which covers most of the American cottons.

The cultivation of the cotton plant demands a climate with special temperature and special rainfall. It is necessary to have a damp atmosphere while the plant is growing, but from the moment it commences to flower dry hot weather, on the contrary, is required. About two months after the sowing, the plants form bushes attain six metres. The flowering period is short. After only forty-eight hours the petals are strewn on the ground.

Harvesting takes place when the bolls and form a fluffy and light mass, which is subject to deterioration in bad weather, so that it is imperative to mobilise all the available hands, including women and children. The seeds are contained in the fruit or "boll" which bursts from internal pressure on ripening and causes the lint to protrude in a fluffy mass.

The pickers advance between the rows of the cotton plants by hand, and stuff it into sacks attached to their belts which reach to the ground. As soon as each sack is filled it is emptied into a vehicle which goes around the plantation.

The separation of the seeds from the fibre—formerly done by hand and constituting a long and costly process—is now carried out almost everywhere by machinery, in "gins". In the United States, for instance, this process is carried out in "ginned" factories, where the cotton is also baled and prepared for export.

The cotton after harvesting is composed of tufts separated from the "boll" and of seeds which are separated in "gins".

The cotton after being compressed is baled, each type of bale varying in weight according to its origin (400 to 600 lbs. for those coming from the United States, and 300 lbs. to 400 lbs. from the West Indies).

The fibre consists of a single individual tube, which flattens and takes on a natural twist on drying. The twist is a useful asset to the spinner, as it enables the fibres to cling together during the process of drawing out. The length of the fibre, or "staple" as it is commonly termed, varies from about $\frac{1}{2}$ inch to 2 inches, or slightly over, and on this depends the fineness and, to a great extent, the quality of the yarn produced.

The length of the staple is of such importance that on it is based grading of the cotton divided into long or short stapled grades. The first comprise staples from 1 to 2 inches, according to the country of origin; the short stapled varieties comprise staples under 1 inch in length.
The world production of cotton, which for the period 1889-1898 reached annually about 22 millions hundredweights, rose from 41 millions per annum in 1904-1908 to 48 millions between 1900 and 1913. From 1917-1922 the world production maintained a level of about 40 millions per annum, omitting cotton produced in China but not exported (about 9-10 million cwts.). In 1923 the world production, including that of Russia, was 42 million cwt. and in 1924 52.8 million. Of the total amount produced 65-69 per cent. comes from the United States and there follow in order of importance British India, China, Egypt, Russia and Brazil.

**Technology**

Prior to reaching the carding department the cotton passes through the following processes.

**Cotton Room**

Bales are stored in this room and the required number of each variety for a particular mixing are brought together and uncovered. After opening by removal of the steel bands surrounding the bales, the jute covering is carefully picked away and the bales then broken up by hand or passed in sections into the hopper of a bale-breaking machine direct or by lattice feed. The breaker is a large irregularly-shaped box, the mechanism of which is well enclosed and away from the worker. Hand pulling of cotton is now almost entirely superseded by the mechanical method or use of the hopper bale breaker, which takes in the whole bale and breaks it up quickly, satisfactorily and economically.

**Mixing Room**

Preparation prior to carding.—This room contains large bins for depositing cotton mixings and is occasionally used for conditioning the cotton by exposure to air and moisture, though modern opening machines render this unnecessary for most classes of cotton. The cotton delivered into these bins is frequently stacked by girls temporarily brought from the carding room, but more suitably by men from the blowing room. The cotton is removed by raking it down from the front of the bins and is then conducted by a moving lattice to the openers.

**Blowing Room**

In this department the cotton is further opened out and then spread into a lap and rolled up for transfer to the carding engine. The opener is a covered-in machine somewhat similar to a bale breaker. In it the cotton is subjected to rapid beating for dirt removal and is then drawn by an exhaust through slowly revolving dust cages. The exhaust removes the dust through a duct into an outside dust chamber. The cotton is then passed through calender rollers and wound on to a lap by lap rollers. If a double beater machine has been used the rolled lap is taken direct to the carding engine. From the single beater machine it passes to a scutcher. Vertical openers are sometimes employed. These have a vertical shaft through the centre, to which is attached a series of circular discs with steel beater arms on the circumference of each disc, the whole being enclosed in a perforated inner cover which allows dirt to pass to the space between this and the outer casing, the cotton entering below, mounting upwards with the revolving discs and leaving at the top.

**Dangers and hygiene.**—Owing to the working parts of the bale-breaking machine being so well boxed in, they cannot be considered dangerous, but it is extremely dirty on account of the very fine fluff created by tearing. Exhaust removal permits of complete covering and appears to be the best solution. Where it is customary to employ women for bringing in the bales, opening out should be performed by men.

The gearing wheels of the lap rollers and beaters should all be completely covered in, the calender wheels and cogs should be entirely covered by guards, and a projecting beater shaft should either be cut away or a loose sleeve fitted. The hinged covers of beaters and doors in front of the cages should be fitted with automatic locking devices to prevent them being opened while the machine is running. Excessive precaution is necessary in removing the lap as severe injury may be caused to the hands and arms by the lap rollers, particularly by the practice of starting a fresh lap while the machine is running. There is very little danger attached to vertical openers. Where the laps approach 60 lbs. in weight men should always be employed.

**Card Room**

Here the separated cotton is carded or brushed out by a machine known as the carding engine, the objects being: (1) to straighten out and render parallel the individual fibres; (2) to remove short and immature fibres, twisted or knotted fibres (“neps”), scraps of husk or
leaf, "bearded motes" (hairy seeds), dirt, etc.; (3) to convert the lap into a narrow ribbon or "sliver". For large and medium counts single carding suffices. For fine and semi-fine counts re-lapping after carding, followed by combing, is necessary. The cotton is passed over a cylindrical comb, between cylindrical and flat brushes and on to a drawing-off apparatus. Knives placed below revolving cylinders remove bearded motes, and several dirt bars allow short fibres, sand, etc., to drop into a dirt chamber. At the front of the carding cylinder, and running at a less surface speed, is a wired doffer cylinder for stripping off fibres and by a revolving brush, the spindle of which is dropped into the bearings provided, and its wires brought into close contact with those of the cylinder and doffer. Grinding is carried out by means of a carborundum or emery covered disc, which revolves and traverses the length of a movable steel rod in each direction, sharpening the wires on both sides. This operation is necessary twice weekly to fortnightly, according to the class of cotton going through.

Carders, usually trained as fitters of carding machinery, attend to the carding machines. Strippers and grinders are mostly "handymen" without a mechanic's training, but require considerable dexterity as they have to attend to the starting and stopping of the cards, prepare and replace straps and bands, oil machines, and clear away waste, as well as carrying out the stripping and grinding. Card tenters are usually women.

Dangers and hygiene. — Where women are engaged in tenting, lap carrying should be done by men, as the lap sometimes weighs 60 lbs. In fine spinning mills girls under eighteen years of age act as tenters, but should
not be engaged on lap carrying, which in their case would be conducive to lateral curvature. The duty of card tenters is to change the sliver cans and keep the machines clean, but girls should not be allowed to start or stop the machines.

Insufficient or bad spacing of carding machines has been a frequent cause of accidents and interferes with the provision of adequate guards owing to lack of space, and should therefore be avoided. All gear wheels should be well covered in. A deposit of fine fluffy dust is always occurring in the neighbourhood of carding machines, and tenters are continually engaged in picking waste and wiping down, every precaution being necessary to ensure the utmost safety during these operations.

Until recently stripping was effected in the open, to the accompaniment of a cloud of dust, but exhaust systems permitting of dust removal through a flexible tube leading from a close fitting tin cover to a pipe junction are now usually provided. Dust suction by means of a vacuum cleaner is sometimes applied as an alternative, but the use of a stripping brush once a week may be required in addition. The doors known as stripping doors, because open for purposes of stripping and grinding, should be fitted with a safety locking mechanism.

Danger is apt to arise from the main driving belts of carding machines during reversing necessary in the process of grinding, and opinion is divided as to the best methods of eliminating the risk involved. Certain mechanical devices have been introduced for reversing without belt crossing, but have not so far met with much favour. Women and young persons should be forbidden to start and stop the machines during this operation.

**Combing**

The sliver from a carding engine may be taken direct to a drawing frame (usually done with lower counts), may be re-carded, or may be submitted to a process of combing out the short fibres and improving the parallelism of those remaining. The second method is not so often followed, but, where adopted, requires the re-conversion of the sliver into a lap by means of a Derby doubler. Combing out is necessary for fine counts, and is becoming increasingly adopted for the medium variety. Before treatment by the comber, the sliver must be transformed into narrow even laps by a sliver lap machine and ribbon lap machine, the second not always being necessary in the case of medium counts. The slivers pass over guides between drawing rollers and two pairs of calender rollers, and are then wound as a lap on to a bobbin.

The comber machine usually deals with six ribbon laps simultaneously. Each roll is unwound and passed by feed rollers to a combing cylinder, where it is held by nippers, while a series of fine needles pass through it, removing the short fibres. It is then pieced up to the preceding section and drawn through a linear top comb. The combed fleece, as in carding, is converted into sliver, which passes through a coiler into a can. The needles on the cylinder are brushed free between each combing action.

**Dangers and hygiene.**—The making of the first turn on the lap frame is the most dangerous part of the work. The lap should not be threaded with the machine running; to obviate this, covers should be provided, which prevent the machine starting until closed. The tenter, usually a woman, replaces cans and laps, and cleans and oils the machines.

**Drawing**

Sliver from the cards, after the extra process of combing, must be submitted to re-arrangement of this fibre by a joint process of drawing and doubling, to ensure a final perfection of the original mixing, a further parallelisation, straightening and polishing of the fibre, and a more constant equivalent between weight and length of the sliver. Short machines, usually coupled together in rows, with gangways at intervals, are used, each frame taking, from two to eight series of sliver. The slivers travel through holes in a guide plate, over a spoon, between rollers, to a succession of drawing rollers, eventually forming a strand, which passes between calender rollers and is coiled into a sliver can. The slivers may be subjected to a second, third or fourth drawing to produce the requisite parallelism. Drawn frame tenting is particular work, and requires careful selection of personnel. The tenter threads the ends into the machine, and pieces up when there is a break. She replaces the full cans with empty ones, and threads the ends from the former into the next machine, besides cleaning and oiling the machinery.

**Dangers and hygiene.**—The end shaft beneath the frame may cause accidents to cleaners if not protected, and should have a bent sheet iron
cover, or be tubed. The gear wheels, calender rollers and cogs, the drives and coiler mechanism should be adequately protected.

**Roving**

The object of this process is the production of a thinner but sufficiently strong variation of the sliver, capable of being wound up on a bobbin ready for drawing and spinning, and technically known as roving.

The sliver is converted into a thick cord by a slubber or twisting machine, and further thinned out by either one or more machines known as fly bobbin or speed frames. These frames are built on the same principles, but looks for broken ends of single rovings, and, on detecting such, stops the frame, re-threads the flyer, and pieces up. She also does the doffing (replacing the full bobbins on the creel for empty ones) and creeling (changing the empty bobbins on the creel for full ones). She also cleans off waste and cleans the whole frame periodically, after stopping the machine. The slubber tenter has no creeling, but supplies a frame with sliver and pieces up. Back tenters place the bobbins in skips for removal to the hoist. A skip may weigh up to 90 lbs., and is usually dragged by a hook, the draggers being sometimes women, often girls or boys. In some cases a bogey running on lines collects the skips.

**Fig. 11.** — Spinning frame (height of bench about 2 ft. 9 in. from the ground).

The spindle gauge and size of the spindles and bobbins are diminished for each successive drawing out of the roving, the machines being termed, intermediate roving and jack frames. The slubber, unlike the other frames, has no bobbin creel. For the succeeding drawings the roving is taken from the bobbins through drawing rollers to flyers and bobbins, and the rovings are doubled to minimise irregularities. Every turn of the flyer puts a twist into the roving. The tenters for these frames are usually women and girls. The tenter often has a helper to move cans, and assist in doffing. A tenter

**Dangers and hygiene.** — Accidents on speed frames mostly result from cleaning cloths and waste being caught by gear wheels or between moving belts and pulleys. Cleaning near a danger zone while the machine is running should be avoided, and guards should be provided for projecting parts of the machinery. The door of the jack box should have an automatic lock, and the draught roller gear of the head stock should be completely covered in, as well as the bobbin driving wheels and bevel wheels driving the individual bobbins and spindles. The lifter rack and pinion, though moving slowly, re-
quire a guard to prevent fingers being dragged into the nip when picking out waste. Metal covers are generally provided for the spindle wheel. Wooden covers found on older machines constitute a danger owing to losing their fit through warping or cracking, and getting pushed off during cleaning. Dropping of balance weights has resulted in accidents, and it is advisable to have a hole drilled through the weight and a swivel link fitted, or to replace balance weights by weighted levers.

**Spinning**

In this final process the ultimate roving is further drawn out to give the required count, and is subjected to considerable twisting to give the fibres the requisite amount of cohesion and required tensile strength. This can be done up to a certain point by a flyer frame. Arkwright’s frame was on this principle, and later improvements resulted in the process known as throstle spinning, which is now, however, but rarely followed in cotton spinning. For spinning, which is now, however, but rarely followed in cotton spinning. For the continuous process of spinning and winding it has been replaced by the use of the ring frame, and for the intermittent process the self-acting mule is used.

**Mule Spinning**

This type of spinning is the mechanical equivalent to the original hand method, whereby the fleece was drawn out twisted by the spindle and revolving whorl and then wound on to the spindle itself. The bobbins are pegged and tied in with the drawn-out wool. For the continuous process of spinning and winding it has been replaced by the use of the ring frame, and for the intermittent process the self-acting mule is used.

**Dangers and hygiene.**—The spinning mule is a dangerous machine, and special attention has been paid to the best means of minimising risk by fencing off specific parts. In England the Home Office Regulations of 1905 specified the parts to be guarded, and made certain demands as to cleaning. Working and cleaning between the carriage and the creel should be forbidden unless when the former is stopped on the outward run, and the machine must not be re-started until the minder is sure that no one remains in the danger zone. The starting rod should be pegged or wedged, or provided with a special locking device to prevent slipping.

Slight accidents often occur in the mule gate. The custom is to have the feet bare, and, as the floors are of wood, splinter wounds are frequent. The feet are also injured by coming in contact with carriage wheels, scrolls, stops, draw bands, and pulley guards, and injury is also received by stumbling over these. Crushing is often due to insufficient space between pillars in the mule gate and the carriage. A smooth projection, which can be felt by the foot in time to permit of side stepping, is sometimes placed with advantage at the bottom of the pillar. Hands are often injured through slipping during wiping down or in piecing, and draught gear wheels at the back of the head stock should be provided with efficient guards. Slight accidents also happen through picking waste from moving bands, even when pulleys and drums are well covered. Where this is not the case, the injuries may be
severe. Replacing the driving strap on to the line shaft pulley after repairing presents danger, and if a ladder is used it should have well secured hooks for fixing on to the shaft, but the best method for reducing the risk is the placing of a small wooden platform over the head stock at the creel end, at a sufficient elevation to enable the minder to manipulate the belt with ease.

Fingers may be caught between two faller sickles if these are too close together, but this is avoided by having sufficiently large bosses. The whole of the back of the head stock should be completely fenced with a sheet iron pulleys must be sufficiently covered to guard the nip. Sloping this guard towards the carriage prevents rough contact with the feet. If upright pulleys are used, they must be sufficiently covered in to guard the nip.

Carriage wheels are mostly provided with nip guards, but may be completely covered. The rim band tightening pulley in front of the head stock should be perfectly covered, the cover having openings of sufficient size only for the free passage of the rope. The pinion wheel must be fenced and the quadrant scroll provided with a cover which takes in the nip. Fuller stops should be covered in to protect the fingers.

Any guards displaced, broken or removed for repair must be replaced.

Ring Spinning

In this process, drawing, twisting and winding are effected simultaneously. The machine is an oblong frame, which spins on both sides, and has its creel running along the centre. In front and below the creel on each side is a roller beam with three rows of draught rollers, and in front and below again is a ring rail holding
hardened steel rings 1½ to 1¾ inches in diameter, firmly fixed to the rail, each ring having a polished flange, to which is hooked a bent piece of tempered steel wire known as the "traveller". A spindle with the foot resting in its bearing on the spindle rail runs vertically through each ring. Ring frames are used for low and medium counts. The roving is passed from a bobbin between two rows of draught rollers, through a guide, then threaded through the traveller, and attached to the bobbin tube or pirn placed on the spindle.

Ring spinning is the most extensively adopted method in all countries except England. Female labour is more extensively utilised than in mule spinning, the process being less complicated and less dangerous. Young girls are taken on as band-reachers for the process of banding (passing the band over the rollers), done at regular intervals when the machine is stopped, unless with a single roller, where it can be done while the machine is in motion. Doffers, whose chief work is to change full bobbins or tubes for empty ones while the machine is stopped, are usually recruited from band-reachers. They also assist the spinner to clean and piece up. The spinner is usually an adult female, who attends to the creeling and cleaning of the frame, assisted by a male jobber who attends to belts, ropes, oiling and adjustment. A youth works a bogey, which runs on a line carrying skips of bobbins.

**Dangers and hygiene.**—These machines are now very well fenced, the defective ones being usually those of an older type. The draught gear wheels at the head stock should be completely guarded, and the lifting gears effectively protected. Banding on frames with double rollers while the machinery is running has caused serious accidents, and should not be permitted.

**Subsidiary Processes**

Yarns may leave the spinning mill in the original cops, or may be submitted to further mechanical processes. In the former case they are placed in a conditioning room, generally in the basement, for the absorption of moisture, mostly with the assistance of a watering can, then packed in skips for transportation. Twist yarn may be wound and beamed, or be beamed after doubling, or be doubled or wound and doubled or reeled, or doubled and reeled, and weft may be doubled with or without preliminary winding, and run on to pirns. Doubling may involve clearer winding and gassing.

**Cop Winding**

The winding on to bobbins is done on a long double-sided frame, the thread or threads being taken from a cop or cops over a cloth covered drag board running the length of the frame, through guides and on to the bobbin. Pirn winding is effected on double frames with bobbins or spools above and in the centre, and pirn spindles along each side.

**Clearer Winding**

This process is extensively used after doubling, to remove soft parts and lumpy defects in the double thread, or in single yarn direct from the spinning room. Clearer gauges, steel plates, each having a central slit regulated to prevent the passing of thickened parts, are fitted on to a bar between the two sets of bobbins. Piecing is done by a weaver's knot, or by means of a hand mechanical contrivance known as a Barber knotter, strapped to the winder's left hand, which also cuts away knot ends.

**Reeling**

For shipping, single or double yarn from cops or bobbins is run into hanks, compressed into a bundling press and made into rectangular parcels. Cop winding is usually done by women and requires very close attention, their work consisting in piecing up, replacing the cops, doffing and keeping the frames clean. Pirn winding is usually done by men and the winding often stopping automatically when the thread breaks.

**Danger and hygiene.**—Winding and reeling frames are not very dangerous. The driving ends should be closed in and a fender guard provided for the driving belt and pulleys and all gear wheels should be out of the way or covered in, and where double tin rollers are utilised a nip guard should be provided.

**Doubling**

This consists in twisting together for strengthening purposes two or more threads and is done on ring frames similar to those used for ring spinning, on flyer frames or on twiner mules. Wet doubling involves passing the yarn through water before twisting and is effected by providing a series of copper troughs or a continuous trough between
the creel and the rollers. This work is usually done by female workers and consists chiefly in creeling, which is done with the machine running by taking out the bobbin, attaching the yarn to a fresh one and placing it in the creel. The doublers also attend to the cleaning of the frames and are aided by the layers-on who carry empty bobbins from a skip to the frames. Doffers assist with creeling and doffing and assistant doffers help with cleaning, change the travellers on the frames when there is a change of counts and collect the waste. The set carriers bring skips of full bobbins and has the assistance of a picker and a twirler on, the latter being equivalent to a scavenger.

**Gassing**

This process consists in passing the double thread through a Bunsen gas jet for the purpose of burning away the line down from its surface and is done on a double frame with 50 to 70 spindles on each side. The yarn is drawn by revolving bobbins over a drag board through guides through the flame and through a traverse guide to be rewound. The gassers, usually women,

Fig. 46. - Ventilation piping in a Belgian spinning room.

(Note safety devices in front of the wheels of the male carriage.)

or spools and distribute them and remove the full spindle bobbins.

**Danger and hygiene.** - The methods to be adopted for accident prevention are similar to those mentioned in connection with ring spinning. **Twiner doubling** is carried out on the intermittent principle by machines of the mule type. An ordinary English twiner is after the style of a spinning mule reversed and twisting takes place while the mule carriage is on its outward run and the yarn is wound during the inward run. French twiners are similar alike to the spinning mule. The mule twiner attends to the machines attend to the replacing of the bobbins, fill and empty the skips, clean the machines, except where a vacuum apparatus is used for dust removing. Young girls do the sweeping out, supply the gassers with empty bobbins and remove waste.

**Danger and hygiene.** - There is not much danger of accident from these machines provided the usual precautions are adopted, but the process is objectionable on account of the diffusion of burnt cotton fibre throughout the atmosphere. It is particularly irritating to the conjunctiva and the mucous membrane of the throat or nose.
With bad ventilation the dust hangs about in a cloud, subsequently forming a scum of dirty brown powder on the machines and floor. An extraction fan for the whole frame is not practical and the practice of hooding the machines offers the best protection. An efficient type of hood practically covering the top of the machine has a tin ceiling along its whole length, forming with the upper parts of the cover an air chamber and this ceiling has a double row of circular openings, so arranged that each one corresponds to a gas jet. A duct from the centre of this air chamber joins the main duct leading to an extraction fan chamber. Care must be taken to secure a sufficient number of properly disposed inlets to balance the pull of the fan, a precaution often missed. For doubled fine yarns a greater flame exposure is often given and is effected by a longitudinal slit in front and a row of eighteen small gas-jets at the back, the two rows being coupled to an exhaust leading by a duct into a fan chamber. Several frames may share a fan or there may be a fan to each frame. A water chamber between the frame and the fan chamber prevents sparks being blown into the outside air.

**Beaming**

Cotton spinners and doublers often have to wind twist on to warpers’ beams before sending it to the weaver. The beam is a wooden roller 5 inches in diameter and 60 inches long with flanged iron ends 20 inches in diameter. The ends of a steel shaft piercing this beam are placed in slot bearings on a cylinder which imparts a necessary motion. The creel is placed behind holding 500 to 600 bobbins in rows, the warp threads are taken across to the beam and about 20,000 yards of each are wound round it. The machine stops automatically when a thread is broken or the required length of yarn has been wound round the beam. An adult female tenter or beamer looks after the machine and does the necessary piecing, creeling and cleaning, while male packers replace the beams on the machines.

**Danger and hygiene.**—Ordinary precautions as regards fencing are necessary. The bleaching of cotton involves “washing” or “scouring” and “chloring”. The “washing” is intended to eliminate the natural impurities of the cotton and those originating in the operation of weaving.

The cotton in hanks is also “mercerised”; for this purpose it is first plunged into a solution of caustic soda, and red turkey oil, or an equivalent proportion of castor oil soap. The solution is brought to boiling point with a view to eliminating the waxy material and rendering the thread permeable to the caustic soda. The threads pass through wringing machines; they then are placed in a cold state in a strong caustic soda solution. The cotton on contact with the soda undergoes a transformation of its molecular structure and the twisting of the thread is modified, an important factor in procuring brilliancy during mercerisation.

**Historical Review**

The early history of the spinning and weaving of cotton is associated with India and dates back some centuries before the Christian era. Cotton manufacture was introduced into Europe by the Moors and cotton was grown, spun and woven in Spain in the tenth century and its manufacture became established in Italy some 400 years later. Columbus found the natives of the West Indies and of the American continent weaving the fabric, which must have been known in America from an early period.

The advent of the industry into England is commonly assigned to Flemish emigrants who settled in Lancashire and subsequent to the rapid development of the industry there, owing to improved mechanical methods, it spread at a later date to other countries of Europe, Asia and America. Hargreaves’ spinning “jenny” (1764), Arkwright’s spinning frame (1768), Crompton’s spinning “mule” (1779), Cartwright’s power loom (1807), and Roberts’ self-acting mule (1830) brought about a rapid technical development of the industry and, coupled with the application of steam power and at a later date of electrical power, led to its expansion on an enormous scale.

In the United States there were only 4,500 spindles in 1805, but in 1831 the number of cotton factories had reached 801, with 1,246,708 spindles, 33,433 looms and 57,446 workers. In 1914 the number of factories had risen to 1,928, the spindles to 30,815,751, the looms to 672,734, and the workers to 393,404. In 1919 the number of factories was 1,496, with 33,718,953 spindles, 692,169 looms and 446,852 workers. In 1921 446,762 women were employed in the cotton industry.

In 1885 the world spindles had
reached 71,250,000, of which 40,000,000 were used in Britain. Of the 143 millions of world spindles existing in 1911, 58 million belonged to Great Britain. In 1898 Great Britain possessed 1,151 factories with 9,383,000 spindles, 100,000 looms and 237,000 workers; in 1871 the number of factories had risen to 2,671, the spindles to 39,527,920, the looms to 514,911 and the workers to 482,903. In 1911 the English textiles industries gave occupation to 1,317,565 workers, 746,154 of whom were women, 61.5 per cent. of the latter worked in the cotton industry.

According to more recent statistics (1924-1925), returns for the cotton industry are as follows:

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of factories</th>
<th>Number of spindles</th>
<th>Number of looms</th>
<th>Number of workers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Britain</td>
<td>1,917</td>
<td>50,902,954</td>
<td>768,197</td>
<td>630,000</td>
</tr>
<tr>
<td>United States</td>
<td>1,706</td>
<td>37,382,998</td>
<td>762,808</td>
<td>420,000</td>
</tr>
<tr>
<td>France</td>
<td>572</td>
<td>9,355,000</td>
<td>181,000</td>
<td>197,500</td>
</tr>
<tr>
<td>Italy</td>
<td>580</td>
<td>4,700,000</td>
<td>130,000</td>
<td>260,000</td>
</tr>
<tr>
<td>Germany (1938)</td>
<td>372</td>
<td>10,060,000</td>
<td>240,700</td>
<td>375,000</td>
</tr>
<tr>
<td>India</td>
<td>336</td>
<td>8,315,275</td>
<td>131,485</td>
<td>396,887</td>
</tr>
<tr>
<td>Japan</td>
<td>294</td>
<td>5,160,000</td>
<td>197,500</td>
<td>353,371</td>
</tr>
<tr>
<td>Belgium</td>
<td>70</td>
<td>2,120,000</td>
<td>29,330</td>
<td>19,350 (?)</td>
</tr>
</tbody>
</table>

The following returns for active spindles in the various cotton-spinning countries were published by the International Cotton Federation in 1928, for the half year ending 31 July 1928. Great Britain, 57,136,000; United States, 35,542,000; Germany, 11,153,000; France, 9,770,000; India, 8,703,000; Russia, 7,311,000; Japan, 6,272,000; Italy, 5,189,000; Czechoslovakia, 3,663,000; China, 3,504,000; Brazil, 2,610,000; Belgium, 2,970,000; Spain, Poland, Switzerland, Canada, Holland, Austria, together had 8,245,000, while Mexico, Sweden, Portugal, Finland, Denmark and Norway possessed about 2,361,000.

**The Effect on Public Health**

During the short preliminary stage of the mechanical era in Great Britain, when the location of factories was governed by the presence of water-courses and mainly away from centres of population, the difficulty of obtaining an adequate amount of child labour resulted in the importation of juvenile labour from poorhouses in the south. These juvenile apprentices were badly housed, badly clothed, badly fed and cruelly supervised, and the factory colonies in which they were herded together became foci of infection to such an extent that the prevalence of smallpox and typhus resulted in Government investigation by a specially appointed Board of Health in 1796, and, ultimately, in regulation of the class of employment by the passing of the first Factory Act in 1802.

The second phase of development, in which steam was substituted for water-power, creating concentration in and around the towns where there was a plentiful supply of free child labour, caused the evils of malnutrition, fatigue and disease again to proceed unchecked, and it was not until 1833 that regulation of this system of juvenile employment was introduced under a Factory Act which dealt with hours of labour, holidays, sanitation and education, and provided for the appointment of inspectors to enforce its provisions. The requirement of a certain physical standard prior to employment of children and young persons had a salutary effect in diminishing child labour.

In the Factory Act of 1844 the medical examination of children and young persons prior to employment because the special duty of certifying surgeons appointed for the purpose, and the type of certificate demanded and conditions attaching thereto put an end to much abuse possible under the previous system.

The second great evil brought about by concentration in towns was that of overcrowding and insanitary housing. Factories were being built at the rate of 100 per annum in connection with the cotton industry alone, and a further concentration of population due to the expansion of other textile and distributing industries and subsidiary trades, as well as the rise of coal mining, was occurring simultaneously. The population of certain manufacturing towns increased six- or seven-fold, and no form of local municipal government capable of regulation of housing to meet the increased demand existed, so that constructions of the worst type were erected, the houses in many cases being cellared to provide
accommodation for hand looms, and the sanitary accommodation provided being of a most primitive type. Water supplies were inadequate and wells were often sunk in polluted ground.

These conditions, coupled with faulty nutrition, favoured the spread of disease and infection, and as a result of a report issued by a Health of Towns Commission the Public Health Act of 1848 was passed and a General Board of Health established. A succession of Sanitary Acts followed, and, finally, corporations were empowered to demand the removal of badly constructed slum houses. But an inequality of improvement in the housing and sanitation of manufacturing towns has resulted from the fact that in Britain many of the legislative provisions are adoptive by local authorities rather than compulsory, and, consequently, even the passing of a century has not sufficed to eradicate the damage done to public health by the unregulated tide of population which set in during the early days of the cotton spinning boom.

The baneful effects of housing and overcrowding have already been referred to. Climate must now be considered as being the principal external factor from the health point of view, not only for the workers harvesting the cotton, but also for those engaged in its industrial manipulation.

The growers and pickers are liable to the diseases peculiar to hot and damp climates. The various investigations effected have revealed the frequent incidence of pellegra, ankylostomiasis and particularly of certain types of skin diseases due to certain parasites of the plant (especially parasites of the seed).

It is well known that it is climate which determines the selection of a suitable area for the industry, which demands a moist, equable climate — a fairly constant rainfall and a high degree of humidity apart from rainfall. Cotton spins and weaves easier and with less breakage in a warm, humid atmosphere, and differentiation of locality in accordance with climate is even carried to the extent of selecting sites for fine spinning as opposed to coarse or medium spinning. The damp climate required favours such diseases as rheumatism, with attendant heart affection, nasal catarrh, adenoids and tonsillitis, and these are prevalent in cotton districts.

Certain outbreaks of smallpox in the cotton, districts have been suggested to be due to infected cotton, which has transmitted infection from negro cotton pickers suffering from a mild type of the disease, the nature of the cases and the persons affected pointing to this possibility, though, of course, no absolute certainty exists on the subject.

Dust Production

The various processes involved under the generic term of cotton spinning are dust producing, though not by any means in equal degree. The greatest offenders are the preparatory processes, whilst the subsidiary processes, with the exception of gassing, offend the least in this direction. As regards the middle processes, it has previously been made plain that the cotton is thrown dusty processes are all extraneous matter, and from most of the short fibres, when it leaves the card. So that the comparatively small amount of dust which arises during combing, drawing and roving consists of the very short fibres which have been removed later. Most of the so-called waste, however, collected directly from the draft rollers by the top and bottom clearer rollers, with which all these are provided, and there is also a brushing and clearing device for the combers. This method of cleaning the draft rollers also applies to both types of spinning. That the atmosphere in these departments does contain a certain proportion of this class of dust is shown by the deposit on the frames, but it does not appear to exist in sufficient quantity to affect either the comfort or the health of the worker.

The really dusty processes are bale breaking, opening, scutching, and carding, though even in these the amount and character of the dust to which the worker is exposed varies considerably, the main factor in the variation being the class of new cotton being used. Where bale breaking is done, cotton by hand all the dust freed by pulling the tufts of cotton asunder gets into the atmosphere; but, as previously stated, this practice is now almost extinct. Where there is much mixing of cotton and fair-sized slabs from the different bales are placed on a lattice feeding a bale breaker, there is a considerable amount of unavoidable dust. When a bale of cotton, either whole or divided up into a few parts only, is placed directly into the hopper of the breaker the only dust to be noticed is seen in the form of a slight cloud rising from the back of the machine. When the broken up cotton is removed by exhaust, instead of by lattice, the back of the machine is quite closed in, and under such circumstances, if all parts are in good repair and working well,
there need be no dust from this process. There is some dust where the automatic feed hopper is filled by hand or by lattice, but not when kept supplied by exhaust duct. Openers and scutchers are very well closed in, and, as they are provided with exhaust fans and ducts, which carry away a considerable amount of the dust by way of the cages and create a negative inside pressure, they do not cause pollution of the atmosphere.

In the card room proper it is quite common to notice a general haziness of the atmosphere, the density of this depending on the amount of efficiency displayed by the ventilation system and the class of cotton. Cards, although apparently quite well covered in, have various unprotected points capable of distributing dust during their normal working, and to keep this at a minimum it is customary to fix a series of exhaust fans along the outer wall. In a few mills the air is exhausted through a grid placed in the floor at the front of each carding engine. For these exhausts to be effective it is essential to provide for a sufficient inward supply of air at the required temperature, and this can be done through the general plenum system of the mill or by a separate local installation. It is not to be understood, however, that this interchange of air is for the most part worked out on scientific lines, as it could and should be. The dust arising from stripping and the dealing with it have already been mentioned, but it should be stated that the method of producing the exhaust is now invariably by chamber and air pump.

The dust arising in the manner described is generally classed as organic and as vegetable on account of its origin, and though this is fairly correct in the main it must be noted that the variety found in the card room does contain a very appreciable amount of mineral matter. The dust arising from bale breaking consists mainly of short bits of cotton fibre, with some small particles of husk and some proportion of fine sand. When it is considered that its production is due to the pulling asunder of compressed pieces of cotton, its main composition of short broken fibres is easily understood. It is by the separation of the individual fibres in the carding process that the finer impurities, and indeed by far the heaviest percentage of impurities, are released. In the dirt boxes beneath the cylinders one finds, in addition to the short fibres, neps, bearded motes

![Fig. 47. — Ring spinning room in an Italian spinning mill. (Note the small turbines with direct coupling.)](image-url)
and a considerable amount of fine sandy powder, the slightest disturbance of which produces a cloud of dust. Under the microscope this dust shows ordinary sand particles, and a considerable number of crystals of fine silica, of all sizes and various shapes, with the large rectangular variety very prominent. There is also a considerable amount of vegetable debris, cotton fibres, spores and hyphae of moulds and bacteria. As regards the chemical composition of the sandy powder, the results of recent analysis of samples from both Egyptian and American cotton are as follows:

<table>
<thead>
<tr>
<th>Moisture</th>
<th>Egyptian</th>
<th>Moisture</th>
<th>American</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>7.0</td>
<td>%</td>
<td>5.6</td>
</tr>
<tr>
<td>Organic</td>
<td>47.49</td>
<td>Organic and CO</td>
<td>33.78</td>
</tr>
<tr>
<td>CO₂</td>
<td>0.736</td>
<td>SiO</td>
<td>50.91</td>
</tr>
<tr>
<td>SiO₂</td>
<td>38.450</td>
<td>Fe₂O₃ and Al₂O₃</td>
<td>16.145</td>
</tr>
<tr>
<td>Mg</td>
<td>3.652</td>
<td>Mg</td>
<td>15.31</td>
</tr>
<tr>
<td>Unaccounted (K and Na salts)</td>
<td>4.637</td>
<td>Unaccounted (K and Na salts)</td>
<td>100.00</td>
</tr>
<tr>
<td>100.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

These estimations indicate that something approaching half of the fine sandy powder is organic, and that the mineral part is, to a considerable extent, made up of silica in combination. Free silica, though shown by the microscope to be present, is obviously crowded out by organic matter and combined silica, and therefore harmless so far as silicon is concerned. The American sample contained more free silica than the Egyptian sample, and both showed metallic iron from grinding. As the revolving brush used in stripping takes up the cotton from the card and doffer wires, this sandy powder must have formed the principal portion of the dust inhaled by the stripper under the old system. It certainly forms the greater portion of the dusty cloud created when cleaning out the dust boxes under the cards.

In the course of 1923 Chinese cotton, which gives rise to enormous quantities of fine dust, was used in Russia. Conditions in the spinning factories were rendered still more trying because the use of this cotton demanded more frequent cleaning of the carding and combing machines. In Russia there is manipulated in special spinning establishments a particular kind of cotton known as "tchachbout", made from old clothes and old kshtris blankets collected in Turkestan and sent to the centre of Russia for re-spinning. This tchachbout is of a dirty grey colour, greenish-yellow in places, and has a disagreeable odour. As early as the operation of sorting much fine dust is liberated. The tchachbout is never re-spun alone, but always mixed with Chinese cotton or other qualities of cotton. During the whole series of operations dust is liberated in greater quantities than during the spinning of Chinese cotton alone. This dust, besides, remains for long suspended in the surrounding atmosphere. An analysis of the air in one of these spinning establishments provided the following results: 20,560 mgr. per cubic metre in the sorting room; 6,100 mgr. in the drawing and combing rooms. (The dust here is much finer and remains longer in suspension in the atmosphere.)

Temperature and Humidity

The spinning of cotton is carried out with the best results in an atmosphere moderately elevated in temperature and charged with a certain amount of humidity. The temperature must be high enough to render the wax in the fibres sufficiently pliable for twisting, and the humidity must be of such a percentage that the fibres will cling well together during the drawing part of the process. It is common knowledge that a dry or cold atmosphere produces bad work owing to frequent breakages. The heat is frictional, i.e. it is produced by the rapidly moving machinery, and it does not take long after starting in the morning to establish the requisite degree of temperature for the daily task. Usually it is only during the winter months that the air requires warming by steam pipes before commencing work. Although, as previously stated, the naturally humid climate of the Lancashire spinning districts is of great assistance, it is not usually sufficient to keep pace with the temperature produced by a concentration of high-speed machines in a confined space, so that it has always been customary to provide such
artificial assistance as the circumstances have required.

Modern spinning mills are now extensively ventilated on the "plenum" system, which permits of any room being supplied with air filtered from outside atmospheric impurities, of the temperature required and containing the most suitable percentage of humidity for carrying on the work in hand. The air can be warmed, cooled or humidified at will in order to secure the correct balance in the room during all weather and seasons. Spinning mills have never been troubled with excessive humidity for anything approaching the degree to which weaving sheds have been affected. A relative humidity of 50 to 54 per cent. is stated to be quite high enough for successful spinning, and as a matter of successful practice many mills work on much less. It is of course largely a matter of the counts being spun.

Various kinds of cotton do not all react in the same manner to humid air. They may imbibe at the same temperature perceptibly different quantities of humidity in the presence of an atmosphere with the same degree of saturation.

Whilst the thread manufactured in dry air is hard and rough, the same thread made in humid air is compact and smooth. The presence of static electricity in the weaving sheds also exercises a bad effect, rendering the fibres rough and hard. The fibres similarly charged with electricity tend to sprout and subdivide. Damp air, being a better conductor of electricity than dry air, eliminates these disadvantages, since the fibres bend and become pliable instead of straightening themselves. The strength and elasticity of the fibre are equally influenced by heat and humidity.

The spinning mill must therefore have a temperature favourable to the work and material handled, as well as a suitable hygrometric state, which is the indispensable complement of the former.

Research carried out by B. A. Dobson, by the Industrial Societies of Mulhouse and of Rouen, by Beltrami, of Milan, by Willkomm, of Hanover, etc., have shown the optimum temperature for manufacture to be about 21° C. and the hygrometric degree to be about 60 per cent. on an average. However, these values naturally vary in relation to the kind of thread required and the origin of the cotton, for it may vary from 50 to 60 per cent. according to the kind of twist demanded, and even above that for strong twist. It increases with the fineness of the number, up to, for instance, 75 per cent. for No. 110 at 26° C.; Sconfietti cites as the optimum atmospheric condition 20-25° C. with 50 to 55 per cent. humidity in the carding rooms and rooms for preparatory processes, 55 to 60 per cent. in the spinning mill, and 65 to 75 per cent. in the weaving sheds. Certain experts, however, find this scale a little low and quote a temperature between 20° and 30° C., with a humidity rate of between 65 and 75 per cent.

During storing in the cotton room and during mixing it is preferable that the material should be kept in a dry state. For this reason a temperature of between 22° and 25° C. is maintained in the mixing room, according to the nature of the cotton and the duration of the time it is left there. A temperature of about 22° C. should also be maintained in the blowing room, while for carding the temperature should not be lower than 22° C. and may even rise to 25°, according to the nature of the cotton handled. The degree of humidity should not exceed 50 to 55 per cent. except for dyed and bleached cottons.

The operation of drawing demands a humidity rate of from 50 to 60 per cent., with a temperature of 22° to 25° C. Dyed and bleached cottons require 70 to 75 per cent. humidity.

Roving is effected at a temperature and humidity rate which vary according to the nature of the cotton. In general there may be quoted as extreme values 22° to 25° C. with 55 to 60 per cent. humidity.

It is highly advisable to maintain a high humidity rate in the combing rooms, 75 per cent. at 25° C.

The conditions in question vary within very large limits in attaining optimum conditions for spinning. This difference is related to the kind of thread (coarse, ordinary, extra fine); for large counts (generally from 1 to 20) a temperature above 22° C. is not required. In the hot season, however, it is not possible to maintain such a low temperature, and it is necessary to have recourse to ventilation combined with humidification to produce the
necessary coolness. The humidity rate should never exceed 60 per cent. in the carding rooms, 65 per cent. in the drawing and reeling rooms, 70 per cent. for mule spinning, and 80 per cent. for ring spinning. The humidity rate should be as far as possible constant and regular. For the ordinary counts the temperature should be about 22° C. for roving, about 24° C. for spinning, and the humidity rate 55 to 70 per cent., according to the operations.

The most favourable temperature is that which rises in accordance with the fineness of the cotton and the length of the fibre. Suitable humidity rates should therefore be established in each mill. For average counts the temperature may be fixed at 24° C. for the carding machines, drawing machines, roving machines and combing machines and also for spinning. The humidity rate should be fixed at 50 per cent. for the carding machines, 55 per cent. for drawing machines, roving machines, mule spinning, at 70 per cent. for ring spinning, and 75 per cent. for combing.

The temperature is higher in the spinning mills for fine and extra fine counts, where the slightest draught from the outside air causes disturbance of the work of the mule near the exit. During dry winds breaking of the threads is frequent in those mules which are situated near the windows.

A long series of observations made by S. Wyatt as to the action of surrounding conditions in the cotton industry on health and efficiency have revealed interesting data, especially in regard to the weaving mills. It was easily proved that high temperatures exert a baneful influence on the physical well-being of the workers and on their efficiency. When, however, the movement of the air is accelerated, an improvement in health conditions as well as in efficiency occurs. If the wet bulb exceeds 24° C. the internal body temperature increases and efficiency diminishes. In many weaving sheds the average dry bulb temperature was found to be maintained throughout the year between 21.5° and 24° C., whilst in summer the temperature may reach 25.5° C. and even 26°. The average speed of the air movement was about 7.30 metres per minute. In certain workshops the wet bulb registered during the last quarter of the working day, upwards of 21° C. and during the remaining quarter 24°. It is true that the breaking of threads is less frequent and consequently efficiency has a tendency to increase parallel with the increase of temperature and humidity, yet around 24° C. wet bulb, human efficiency tends to fall and the body temperature to be increased. Though the humidity rate is fixed, no remarkable means of adaptation to mitigate such trying conditions, it is not desirable that an effort of this kind should be too often demanded of the workers.

**Lighting**

An enquiry by C. Hanson into conditions in the cotton factories of Massachusetts revealed lighting in these to be inadequate. Too many of the factories had low roofs, small windows and lack of space. It is absolutely necessary that glass roofs and windows should be regularly cleaned, and that walls and ceilings should be whitewashed periodically.

According to Hanson, 80 to 90 per cent. of cases of headache among the workers could be traced to ocular fatigue caused by insufficient lighting.

The third report of the English Departmental Committee on the Lighting of Factories and Workshops gives as a minimum for textile industries in each the following values: about 30 lux for weaving on an ordinary loom, etc. (the American Codes generally require about 22 lux for ordinary work not requiring minute vision), and about 33 lux for ordinary work requiring minute vision.

It is essential that all processes in cotton spinning should be as perfectly visible to the operator as possible, bad lighting being liable to cause accidents, eyestrain and bad work.

In England few mills, with the exception of card rooms, have top lights owing to the general adoption of the storied building, found convenient for steam power transmission. Window space is usually good, but owing to the size of the mules the rooms must be so wide that direct lighting cannot reach the centre. Ring spinning rooms, not necessarily so wide, have usually better conditions. Frame machines are generally placed transversely in order that the light may reach the alleys or gates without obstruction, though in some of the older mills adapted to new machinery, this is not the case. Periodical whitewashing, or painting for lighting reasons, apart from cleanliness, are enforced by the British Factory Acts. Windows should be cleaned regularly, and free from external obstruction. Prismatic glass for deflecting the angle of light is advisable, provided it can be kept in a clean
condition. The only effectual artificial lighting for cotton factories is electricity, and it requires little attention beyond good disposition of the lamps and regular cleaning of these, and has the advantages of avoiding vibration of the atmosphere and presenting little danger of fire. The lights should be arranged in rows above the alleys, about 10ft. above the floor level and 15ft. apart. Passages, landings and stairways should be well lit.

Fatigue

Very few scientific studies on fatigue have been undertaken in connection with the cotton industry, either before or since the reduction of working hours in the Lancashire cotton area, so that definite results for comparison and for determining the value of the change are not available. Prior to July 1919 5½ hours per week were worked — 10 hours for five working days and 5½ hours on Saturday.

The Industrial Fatigue Research Board published a report in 1920 relating to individual differences in output in the various processes of the industry, with a view to illustrating the extent to which production in each separate process depends upon human as opposed to mechanical efficiency. There was a very slight mean variation between maximum and minimum values in both mule and ring spinning, showing the part played by the operator to be very minor. The human factor was shown to be more important in the processes of drawing, slubbing and roving and still more so in the weaving processes. The process which would appear to provide the greatest scope for individual efficiency is ordinary single reeling, watchfulness being the essential quality demanded.

On the whole observations tend to show the extreme difficulty involved in trying to gauge fatigue in the spinning industry by output. The quality of production is in short a question of machine efficiency and as regards spinning rooms, and in a lesser degree card rooms, of temperature and humidity.

In relation to the incidence of accidents, a factory Inspector's report dealing with 1,000 cotton factories, shows the incident rate to rise towards the end of the week, with a considerable increase on Saturday, probably due to a desire to hasten the weekly cleaning of machines by commencing cleaning before the stopping of the engines.

Figures from the Operative Spinners' Approved Society show that lost time due to sickness is not excessive in the industry and labour turnover is a very small factor during normal times.

As regards static fatigue due to prolonged muscular strain, enquiry showed that the strained position taken up in bobbin winding was only temporary and ill-effects were quickly rectified. Winders have a considerable amount of back bending, and are on their feet all day, and this is true of most processes except spinning and doubling. Excessive humidity in the two latter processes sometimes causes the workers to show definite objective signs of fatigue towards the end of the day, while mule spinners suffer to an abnormal extent from varicose veins, varicocele and flat foot.

The monotony of the processes and close attention required often give rise to headaches and nervous depression among females tenders, but a holiday has generally been found to effect the necessary cure.

The lifting and dragging of heavy skips and tins is unsuitable for female labour and should in all cases be done by men or well-grown youths. Girls should not be allowed to carry even 27-lb. laps from scutchers to cards, as they rarely use each shoulder alternately, and the work is consequently liable to produce some degree of lateral curvature.

Amongst the risks should be mentioned that of poisoning: by arsenic amongst the workers harvesting the cotton and those engaged in ginning when the plant has been treated with an anti-parasitic powder having a basis of arsenic; by lead compounds used in dying, etc. Finally, there should be mentioned the risk of explosion due to cotton dust, etc.

Statistics

No complete series of statistics capable of showing the exact extent to which these trade processes affect the health of the operatives has so far been compiled, and as a consequence the best has to be made of the information which is available. Considerable help is afforded by the decennial supplements to the annual reports of the Registrar-General for England and Wales on Mortality of Men in Different Occupations, the value of the tables given in these publications being due to their foundation on comparative mortality figures, which are obtained in
a relatively simple manner. In these reports the occupational mortality is calculated in accordance with a standardisation method described in the article by Prinzling (see article “Occupational Diseases: Statistics”).

The particular report supplying the most detailed particulars about the cotton industry are those compiled for the years 1910-1912. The main table, however, has the fault of its immediate predecessor in that it covers the whole of cotton manufacturing processes, and thus includes weaving, which has a different set of health risks to spinning and other processes. The particular usefulness of the report lies in the fact that it publishes, for the first time, separate figures for the two subsidiary occupations of spinner and grinder and of blowing room operative.

The comparative mortality figure for cotton operatives generally is 911 against 1,114 for the previous period, a drop of 27 per cent. compared with a drop of 21 per cent.... for all occupied and retired. Among operatives generally, mortality figure is 21 above the average, the deaths are below the average up to forty-five years of age, just over from forty-five to fifty-five, and 56 per cent. from fifty-five to sixty-five years.

The excess mortalities are found in nervous diseases, which however show a drop from one-fourth to one-eighth of the excess; other diseases of the circulatory system are more fatal in the general. The mortality from diseases of the digestive system is well over the average for the trade, but only 2 above the general average. Cancer is 85 against 71 for the trade and 59 for strippers and grinders, and is below the general figure; cerebral haemorrhage is 67 against 48 for the trade and 59 for strippers and grinders; suicide is only 6 against 22.

The total mortality figure is 988. Blowing room hands have a total mortality figure of 55 against 22. Cancer is 59 against 71, and suicide is only 6 against 22.

1 According to the report of the Registrar-General (England and Wales) for the period 1921-1923 — which, however, cannot be compared with previous data on account of the modifications adopted in the preparation of these returns — the comparative mortality figure for cotton weavers aged from 30 to 65 and working in dry or damp atmospheres was for all causes of death 1,048. For certain of these causes the comparative mortality figure was as follows: influenza, 393; tuberculosis all forms, 186.7; tuberculosis of the respiratory system, 119.5; syphilis, 16.6; cancer (all sites), 192.1; cancer of the stomach, 35.6; diabetes, 14.4; cerebral haemorrhage, 73.7; diseases of the circulatory apparatus, 103.7; heart diseases, 161.6, of which valvular disease of the heart, 43.3; of the respiratory apparatus, 103.7; bronchitis, 81.9; pneumonia, 70.6; diseases of the digestive system, 174.8; appendicitis, 11.1; chlorosis of the liver, 2.5; chronic nephritis, 42.9; suicide, 33.5; accidents, 11.0.
DEATH RATES PER 1,000 OPERATIVES LIVING AT FIFTEEN YEARS OF AGE AND OVER

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weavers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male Bronchitis,</td>
<td>1.6</td>
<td>0.4</td>
<td>2.0</td>
<td>0.0</td>
<td>2.3</td>
<td>0.9</td>
<td>2.3</td>
<td>1.8</td>
</tr>
<tr>
<td>Phthisis</td>
<td>0.9</td>
<td>0.4</td>
<td>1.2</td>
<td>1.8</td>
<td>1.5</td>
<td>0.3</td>
<td>2.3</td>
<td>0.6</td>
</tr>
<tr>
<td>Other tuberculosis disease</td>
<td>0.1</td>
<td>0.1</td>
<td>0.4</td>
<td>0.3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Cancer</td>
<td>0.6</td>
<td>0.3</td>
<td>2.7</td>
<td>0.6</td>
<td>2.3</td>
<td>0.6</td>
<td>2.3</td>
<td>0.6</td>
</tr>
<tr>
<td>Total death rates</td>
<td>6.9</td>
<td>3.3</td>
<td>14.8</td>
<td>5.7</td>
<td>12.3</td>
<td>4.8</td>
<td>17.7</td>
<td>6.7</td>
</tr>
</tbody>
</table>

The figures quoted certainly show that modern cotton cloth weaving as now regulated can no longer be classed among the unhealthy industries. They also indicate that spinning processes are not so healthy as weaving and, somewhat surprisingly, that winding and warping constitute the most unhealthy branch.

Taking the table as a whole it certainly points to the conclusion that female weavers particularly and female cotton operatives generally are really very healthy. As Blackburn has the highest proportion of married female operatives of any of the cotton towns, which of course means a higher average working age, the rates for the sex are very significant. Dr. Daley states that, in 1921, 11,553 of the married women of the town were employed industrially, 9,694 working in cotton mills; of the married women under forty-four years of age 56 per cent. were occupied, and of those over forty-four years of age 22.9 per cent., the proportions throughout the whole country being 20 per cent, and 10.9 per cent. respectively. It appears to be extremely likely, however, that this excess of married female cotton operatives will have a tendency to interfere with the reliability of the occupational death rate, there being every chance that the deaths occurring amongst those married who have given up work on account of illness, as well as amongst those who have retired, will be registered under the category of "housewives". In favour of the Blackburn figures generally is the factor that they refer to a period of great improvement in humidification methods and of dealing with dust in spinning mills, whilst the Registrar-General's figures deal with a period immediately anterior to the introduction of the improvements. Dr. Daley's statistics when compared with those of his predecessors show very markedly this gain in occupational health. The Blackburn figures also show that cotton operatives have no special liability to contract ordinary infectious fevers.

The figures relating to occupational mortality which have been quoted throw considerable light on the special risk of death from certain diseases where the cotton spinning operative has to look forward to. The diseases so clearly indicated are the non-tubercular affections of the respiratory system and, to a lesser degree, affections of the heart and circulation. Previous Registrar-General's Supplements have also shown that the cotton operative has more than the average liability to rheumatic affections. It is also made clear that whilst phthisis can scarcely be considered as occupational among cotton operatives there is some liability for it to superimpose on ordinary non-tubercular lung affections produced by the dusty processes in spinning mills.

Dr. C. L. Cox, the Central Tuberculosis Officer for the administrative county of Lancashire, arrives at practically the same conclusion in his annual report for the year 1922. He is there able to show by definite figures that both the incidence rate and death rate are somewhat above the county average in districts mainly devoted to cotton spinning, whilst below the average in cotton weaving areas.

There are, however, some definite facts to be gathered from the 1919 report of the Operative Cotton Spinners' Approved Society. During the year, 5,091 sickness and disablement claims were paid to 4,434 of their members, whose total numbers at the end of the year amounted to 29,511 males and 1,634 females. It is further stated that 42 per cent of the male claimants and 35 per cent. of the females were suffering from respiratory complaints, mainly bronchitis, and that rheumatism is a familiar complaint amongst the members.

More definite information has been obtained from the Approved Society attached to the Card, Blowing and Ring Room Operatives' Association, though this has the common fault of not being classified under different occupational headings. However, it is known that the males include in their number a goodly proportion of strippers and blowing room hands,
### TABLE I.— NATURE OF ILLNESSES CAUSING ABSENCE FROM WORK

<table>
<thead>
<tr>
<th>Illness</th>
<th>Males for year ending</th>
<th>Females for year ending</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30/6/1923</td>
<td>30/6/1924</td>
</tr>
<tr>
<td>Accident: injury</td>
<td>47</td>
<td>100</td>
</tr>
<tr>
<td>Accident: septic poisoning</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>Anaemia</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Apoplexy</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Appendicitis and peritonitis</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td>Bladder disease</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Bronchitis</td>
<td>160</td>
<td>247</td>
</tr>
<tr>
<td>Cancer</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Ears and hearing</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Epilepsy</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Eyes and eyelids</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>Haemorrhoids</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Heart and bloodvessels</td>
<td>38</td>
<td>42</td>
</tr>
<tr>
<td>Hernia</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Infectious disease</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Influenza and colds</td>
<td>132</td>
<td>240</td>
</tr>
<tr>
<td>Kidneys</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>Liver</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Neurasthenia, neuritis, neuralgia and hysteria</td>
<td>15</td>
<td>40</td>
</tr>
<tr>
<td>Nervous system (other than above)</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Nose</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Phthisis</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>Pneumonia and pleurisy</td>
<td>32</td>
<td>34</td>
</tr>
<tr>
<td>Rheumatic affections</td>
<td>61</td>
<td>99</td>
</tr>
<tr>
<td>Sexual organs</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Skin (including ulceration)</td>
<td>41</td>
<td>62</td>
</tr>
<tr>
<td>Stomach and bowels</td>
<td>54</td>
<td>85</td>
</tr>
<tr>
<td>Tonsillitis and quinsy</td>
<td>34</td>
<td>37</td>
</tr>
<tr>
<td>Tubercular disease of joints, glands, skin, meninges, etc.</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Other illnesses</td>
<td>46</td>
<td>75</td>
</tr>
<tr>
<td>Totals</td>
<td>772</td>
<td>1,217</td>
</tr>
<tr>
<td>Membership</td>
<td>6,883</td>
<td>6,971</td>
</tr>
<tr>
<td>Percentage</td>
<td>11.21</td>
<td>17.45</td>
</tr>
</tbody>
</table>

### TABLE II.— SICKNESS INCIDENCE PER THOUSAND OF MEMBERSHIP

<table>
<thead>
<tr>
<th>Illness</th>
<th>Males for year ending</th>
<th>Females for year ending</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30/6/1923</td>
<td>30/6/1924</td>
</tr>
<tr>
<td>Septic poisoning</td>
<td>1.50</td>
<td>2.29</td>
</tr>
<tr>
<td>Anaemia</td>
<td>4.43</td>
<td>1.00</td>
</tr>
<tr>
<td>Appendicitis and peritonitis</td>
<td>0.74</td>
<td>1.87</td>
</tr>
<tr>
<td>Bladder</td>
<td>0.43</td>
<td>0.88</td>
</tr>
<tr>
<td>Bronchitis</td>
<td>23.24</td>
<td>33.43</td>
</tr>
<tr>
<td>Eyes and ears</td>
<td>2.61</td>
<td>2.58</td>
</tr>
<tr>
<td>Heart and bloodvessels</td>
<td>5.59</td>
<td>8.01</td>
</tr>
<tr>
<td>Influenza and colds</td>
<td>19.17</td>
<td>34.42</td>
</tr>
<tr>
<td>Nervous system</td>
<td>4.35</td>
<td>8.20</td>
</tr>
<tr>
<td>Phthisis</td>
<td>1.30</td>
<td>1.57</td>
</tr>
<tr>
<td>Pneumonia and pleurisy</td>
<td>4.69</td>
<td>4.83</td>
</tr>
<tr>
<td>Rheumatism</td>
<td>8.86</td>
<td>14.20</td>
</tr>
<tr>
<td>Sexual organs</td>
<td>0.29</td>
<td>1.29</td>
</tr>
<tr>
<td>Skin (including ulceration)</td>
<td>5.55</td>
<td>8.87</td>
</tr>
<tr>
<td>Digestive system</td>
<td>9.44</td>
<td>13.62</td>
</tr>
<tr>
<td>Tonsillitis and quinsy</td>
<td>4.23</td>
<td>5.30</td>
</tr>
<tr>
<td>Other tubercular disease</td>
<td>0.00</td>
<td>0.51</td>
</tr>
</tbody>
</table>

who would be expected to present a high average bronchitis rate and affect the total male figure for this complaint, and this proves to be correct. Likewise it might be expected that the females would show undue susceptibility to colds and catarrhal affections, owing to the high temperatures of the ring spinning rooms and fairly high temperatures of the speed frame rooms, and this again proves correct.

Tables I and II above have been compiled by Dearden from several thousands of paper slips kindly lent by the Secretary of the Society. The second one shows very clearly not only the relative susceptibility of males and females to common diseases, but also how an epi-
demic of influenza affects the incidence of all of them. It will be noticed that the males are particularly susceptible to bronchitis, pneumonia, rheumatism and catarrhal colds, and females to anaemia, nervous affections, digestive troubles, tonsillitis and the contracting of catarrhal colds. It is exceedingly gratifying to find such a low incidence rate for phthisis.

The number of days of sickness per member and per annum amounted in 1923 to 9.8 for the men and 12.6 for the women.

Schmidt has compiled morbidity data relative to 3,880 workers in Baden, 3,009 of whom were women, observed by him during the course of one year. The values given in the following table, based on examination of 315 carders and 556 spinners, as well as 1,267 workers engaged in processes of preparation and 1,742 women workers engaged in spinning, correspond to 1,000 workers of each age group:

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Carders</th>
<th>Spinners</th>
<th>Carders</th>
<th>Spinners</th>
<th>Carders</th>
<th>Spinners</th>
<th>Carders</th>
<th>Spinners</th>
</tr>
</thead>
<tbody>
<tr>
<td>14-25 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory diseases</td>
<td>50.3</td>
<td>101.0</td>
<td>73.0</td>
<td>33.1</td>
<td>106.0</td>
<td>68.2</td>
<td>65.1</td>
<td>181.0</td>
</tr>
<tr>
<td>Diseases of the digestive system and of the liver</td>
<td>44.6</td>
<td>53.1</td>
<td>24.3</td>
<td>11.8</td>
<td>9.6</td>
<td>31.1</td>
<td>16.2</td>
<td>17.8</td>
</tr>
<tr>
<td>Diseases of the locomotory system</td>
<td>14.8</td>
<td>10.6</td>
<td>36.5</td>
<td>17.8</td>
<td>28.8</td>
<td>19.4</td>
<td>16.2</td>
<td>57.8</td>
</tr>
<tr>
<td>Lesions</td>
<td>179.0</td>
<td>144.0</td>
<td>69.8</td>
<td>41.4</td>
<td>38.4</td>
<td>74.7</td>
<td>81.2</td>
<td>569.6</td>
</tr>
<tr>
<td>Other causes</td>
<td>475.9</td>
<td>333.2</td>
<td>364.8</td>
<td>246.5</td>
<td>294.4</td>
<td>267.1</td>
<td>259.8</td>
<td>569.6</td>
</tr>
</tbody>
</table>

In Austria, the Sickness Fund for the period 1891-1895 gives the following morbidity figures amongst its members aged between fifteen and sixty years: for 100 members the number of cases involving incapacity for work was per age group as follows:

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Carders</th>
<th>Spinners</th>
<th>Carders</th>
<th>Spinners</th>
<th>Carders</th>
<th>Spinners</th>
<th>Carders</th>
<th>Spinners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anemia</td>
<td>53.8</td>
<td>45.1</td>
<td>33.7</td>
<td>20.0</td>
<td>11.8</td>
<td>21.4</td>
<td>23.3</td>
<td>16.8</td>
</tr>
<tr>
<td>Nervous diseases</td>
<td>19.5</td>
<td>15.1</td>
<td>15.8</td>
<td>14.1</td>
<td>28.4</td>
<td>14.3</td>
<td>14.8</td>
<td>81.1</td>
</tr>
<tr>
<td>Diseases of the digestive system</td>
<td>126.6</td>
<td>89.1</td>
<td>199.0</td>
<td>86.8</td>
<td>56.8</td>
<td>107.0</td>
<td>59.2</td>
<td>81.1</td>
</tr>
<tr>
<td>uro-genital system</td>
<td>29.3</td>
<td>43.1</td>
<td>49.6</td>
<td>33.6</td>
<td>68.6</td>
<td>42.9</td>
<td>66.8</td>
<td>18.1</td>
</tr>
<tr>
<td>Accidents</td>
<td>4.9</td>
<td>22.1</td>
<td>42.8</td>
<td>29.0</td>
<td>37.8</td>
<td>28.6</td>
<td>59.2</td>
<td>54.1</td>
</tr>
<tr>
<td>Total</td>
<td>409.4</td>
<td>414.4</td>
<td>490.3</td>
<td>582.4</td>
<td>404.7</td>
<td>406.8</td>
<td>365.5</td>
<td>513.4</td>
</tr>
</tbody>
</table>
COTTON INDUSTRY

The mortality figures for the same period per 1,000 members and for the same age groups were:

<table>
<thead>
<tr>
<th></th>
<th>15-30</th>
<th>21-30</th>
<th>31-40</th>
<th>41-50</th>
<th>51-60</th>
</tr>
</thead>
<tbody>
<tr>
<td>All members</td>
<td>5.9</td>
<td>6.8</td>
<td>7.7</td>
<td>9.0</td>
<td>14.2</td>
</tr>
<tr>
<td>Textile workers</td>
<td>6.6</td>
<td>9.0</td>
<td>9.2</td>
<td>13.3</td>
<td>22.3</td>
</tr>
</tbody>
</table>

In the United States a very detailed enquiry into mortality in the cotton industry was effected by A. Reed Perry in 1919 in the town of Fall River, comprising observation of mortality statistics during the period 1908 to 1912, as well as a very careful individual medical examination.

Out of 119,595 inhabitants (1910) in Fall River, covering 24,378 families and lodged in 10,962 houses, more than 82 per cent. were men and 18.1 per cent. women engaged in various occupations, 29 per cent. of the men and 28 per cent. of the women working in the cotton industry.

For each age group the workers as a whole presented a mortality rate from all causes higher than that of the other non-operative groups. This fact is true of the women, but for certain groups the men presented a lower rate than that for non-operative males.

Spinning shows a higher mortality rate than other sections of the industry, with the exception of the lower age groups, where carding shows the highest figures.

The cotton workers of Fall River aged fifteen to forty-four are exposed to causes of death at a rate exceeding by 46 per cent. that for non-operative males of the same age. This risk of death from tuberculosis is 100 per cent. higher than from all other causes and 20 per cent. higher than the risk for other persons.

The enquiry brought to light the fact that out of 100 workers, 18.1 were occupied in carding, 23.2 in spinning, 38.9 in weaving, 19.8 in roving and on other operations.

The mortality per 1,000 and for all causes was for these groups of processes as follows:

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
<th>Both sexes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carding</td>
<td>5.13</td>
<td>9.03</td>
<td>7.01</td>
</tr>
<tr>
<td>Spinning</td>
<td>7.27</td>
<td>8.94</td>
<td>8.65</td>
</tr>
<tr>
<td>Weaving</td>
<td>5.55</td>
<td>6.79</td>
<td>6.06</td>
</tr>
<tr>
<td>Roving and other operations</td>
<td>3.90</td>
<td>6.76</td>
<td>5.81</td>
</tr>
<tr>
<td>All workers</td>
<td>5.57</td>
<td>7.07</td>
<td>6.60</td>
</tr>
<tr>
<td>Unoccupied-males</td>
<td>4.82</td>
<td>4.91</td>
<td>4.86</td>
</tr>
</tbody>
</table>

For the age group fifteen to forty-four, carding presents a mortality which is greater or less than the percentage for non-operatives to the following extent: + 24 for tuberculosis (men) and + 235 (women); for non-tuberculosis diseases — 3 (men) and + 56 (women); for all causes — 5 (men) and + 114 (women). The highest figures are furnished by spinning, where tuberculosis exceeds the percentage for non-operatives by 104 (men) and 207 (women). The other figures in this occupation are 23 (men) and 65 (women) for non-tuberculosis diseases and 50 (men) and 112 (women) for all causes.

As regards women occupied in weaving, the enquiry has revealed the fact that tuberculosis attains the figure of —5 for the unmarried and of + 226 for the married, whilst non-tuberculosis diseases exceed the percentage for non-operatives by 7 in the first case and 110 in the second.

In general, the workers of a given age group are more liable to tuberculosis than the non-operatives belonging to the same age group. Thus, for example, the figures for non-tuberculosis are furnished by spinning, where tuberculosis is 100 per cent. higher than for non-operatives belonging to the same age group and 20 per cent. higher than the risk for other persons.

The incidence of pellagra was greater amongst the women than amongst the men, and this disease occurred chiefly during the period May to August. The rate for respiratory diseases was higher in spring. The troubles due to pellagra at the end of spring and beginning of summer took the form of indigestion, dysentery, headaches, neuralgia, etc. Influenza occurred in epidemic form in autumn.

According to data for the period 1911-1913, assembled by the Metropolitan Insurance Company, occupational mortality
MORTALITY FROM ALL CAUSES AS RELATED TO 100 DEATHS OR TO 1,000 CASES OF TUBERCULOSIS (FALL RIVER U.S.A.)

<table>
<thead>
<tr>
<th>Age groups</th>
<th>Workers</th>
<th>Non-operatives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deaths by tuberculosis per 100 cases of death</td>
<td>Deaths per 1,000</td>
</tr>
<tr>
<td>Men:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15-24</td>
<td>29</td>
<td>1.00</td>
</tr>
<tr>
<td>25-34</td>
<td>65</td>
<td>2.66</td>
</tr>
<tr>
<td>35-44</td>
<td>54</td>
<td>4.51</td>
</tr>
<tr>
<td>45-49</td>
<td>45</td>
<td>2.47</td>
</tr>
<tr>
<td>Women:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15-24</td>
<td>61</td>
<td>2.81</td>
</tr>
<tr>
<td>25-34</td>
<td>59</td>
<td>4.02</td>
</tr>
<tr>
<td>35-44</td>
<td>40</td>
<td>3.76</td>
</tr>
<tr>
<td>45-49</td>
<td>45</td>
<td>3.34</td>
</tr>
</tbody>
</table>

showed the following figures (percentages):

<table>
<thead>
<tr>
<th>Number of deaths</th>
<th>Tuberculosis</th>
<th>Pneumonia</th>
<th>Other respiratory diseases</th>
<th>Heart disease</th>
<th>Digestive disturbances</th>
</tr>
</thead>
<tbody>
<tr>
<td>All occupations</td>
<td>219,507</td>
<td>14.8</td>
<td>8.0</td>
<td>2.2</td>
<td>11.9</td>
</tr>
<tr>
<td>Cotton industry</td>
<td>686</td>
<td>21.1</td>
<td>6.9</td>
<td>2.0</td>
<td>11.8</td>
</tr>
<tr>
<td>Textile industry</td>
<td>2,300</td>
<td>22.0</td>
<td>5.0</td>
<td>3.0</td>
<td>10.7</td>
</tr>
<tr>
<td>Textile industry (women)</td>
<td>1,742</td>
<td>33.5</td>
<td>4.1</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

In Italy Pierotti studied in 1926 the state of health of 800 workers from four cotton factories at Pontederia, 620 of whom were women. The men were chiefly occupied on boiler work and in tending dyeing machines.

The case histories pointed to frequent occurrence of anaemia (affecting 10 per cent. of the women), as well as acute diseases of the respiratory system (21 per cent. for the men, 8.6 per cent. for the women) and forms of rheumatism (chiefly affecting the women workers).

During the examination made by the investigator, 33.5 per cent. of the women and 52.3 per cent. of the men were found to be in good health, chiefly those belonging to the youngest age group; 30 per cent. of the men and 25.8 per cent. of the women, though in fairly good health and free from functional or organic lesions, showed, however, signs of early senility, of loss of weight or of weakness; 12 per cent. of the women and 10 per cent. of the men were in a state of health below the average without, however, showing distinct signs of any disease, and were thus liable to become victims to infectious diseases or nutritional disturbances — those belonging to this group showing signs of anaemia, chlorosis and chronic bronchial catarrh; 4.3 per cent. of the women and 7.2 per cent. of the men were definitely suffering from illness (open or latent tuberculosis, chronic nephritis, epilepsy, neurasthenia, syphilis, etc.).

An enquiry effectuated in some Dutch textile factories in the Twenthe district in 1914 revealed several problems for study. Thus, for instance, it was found that the position of the feet turned outwards certainly favours the formation of flat foot, especially in the case of young tall workers. On the basis of the suggestion of Roth, that is to say, examination of the pulse and respiration in order to judge whether the general state and the amount of fatigue experienced by these workers, a report was prepared showing the pulse rate, respiratory rate and the arterial tension of fifty-four workers, examined on several occasions at different hours of the working day, due consideration being given to the psychic factors, etc.

Of 32 examinations conducted before and after the quarter of an hour's rest accorded to women engaged in spinning, it was found that this rest period favoured a return to the normal pulse rate, respiration rate and blood pressure which had been previously above the normal. In 23 cases the rest period had been prolonged to thirty minutes and a new examination is stated to have shown that this prolonged rest caused no perceptible reduction. In 6 cases the return to the normal state did not occur. Almost the same results were obtained as the consequence of an examination of thirty-nine weavers. In the spinning mills, as well as in the weaving sheds, the workers who complained of fatigue and headaches during work were individuals of weak constitution. The rest period of half an hour was insufficient in their case for bringing about a return to the normal state as regards pulse, respiration, etc. It may be concluded from the above tests that in the majority of cases a rest period of a quarter of an hour brings about an improvement of the general state whilst a more prolonged rest period amounting to half an hour is not more effective in bringing about such improvement.
As this investigation was confined to a limited number of workers, it is intended to continue the research on a larger scale.

Details in regard to the above will be found in the Medical Inspector's Report for the year 1914 (pp. 40 et seq.).

Quite recently (July 1927) the British Home Secretary appointed a Committee to enquire into the diseases due to dust in the cotton industry, as well as proposed measures for combating these.

Pathology

What has already been said in regard to the sources of risk in this industry provides an adequate idea of the pathology of diseases in the cotton industry. It is, however, perhaps advisable to emphasise certain points in regard thereto, as, for instance, mule spinner's cancer, knowledge of which is of recent date.

Among the diseases shown by statistics to be of most frequent incidence, the chief are those affecting the respiratory system; cotton worker's pneumoconiosis (or byssinosis), reported many years ago by Coetson, has since then been made the subject of detailed study.

The effects produced by breathing an atmosphere heavily impregnated with cotton dust are characteristic and indicate a severe irritation of the air passages. Dyspnoea is a prominent symptom, but it is dyspnoea of an undoubted asthmatical type and, according to Collis, differs very materially from the dyspnoea of silicosis, which involves abdominal efforts and not the marked thoracic efforts of those afflicted by cotton dust. There is a dry irritative cough with very little expectoration, the latter being of phlegm, and the typical anxious expression of countenance. The breathing becomes more and more thoracic, emphysema develops and the chest becomes barrel shaped. When the sufferer arrives at this stage, usually after twenty or twenty-five years at the work, he is forced to adopt a sitting position. Occupied Dr. Collis only found 139 per 1,000 occupied, as compared with 231 metal grinders and 434 lace wokers who were forty-five years of age and over.

This observer also discovered that working amongst the coarser grades of cotton, which contains more dust than the finer varieties, has more influence in bringing on the symptoms, 91 per cent. of those working coarse grades being affected as against 72 per cent. on medium grades and 62 per cent. on fine grades. The figures previously quoted show that both strippers and blowing room men are very liable to this type of suffering. Unlike inhalers of pure mineral dust, they are not specially liable to the supervision of tubercle phthisis.

An enquiry by Schmidt in 1924, effected in the spinning mills of Baden, also revealed the fact that affections of the respiratory passages due to dust by themselves are not to be considered, but that they have to be considered in connexion with other affections, the incidence of which is often much higher. It is certain that cotton dust plays its part in the production of catarrh of the respiratory passages, but certain working conditions attenuate or eliminate the resistance capacity of the body. The standing position and the movements required by tending running machines are the chief cause of fatigue. Added to this, the necessity of breathing a dusty atmosphere in damp heat is also a factor favouring functional troubles at the outset and later anatomical derangement of the respiratory system. The physical development of young workers is naturally impeded and obstacles to their physical development are further complicated by social conditions (Schmidt). Lately has been shown that, besides the irritative effect on the respiratory mucous membrane, and on the conjunctiva, of the burned products from the gassing of doubled yarn. Healthy workers soon get accustomed to this type of dust, but it would certainly appear to be deleterious to those already suffering from blepharitis or conjunctivitis, or from affections of the respiratory tract. Workers in badly arranged gassing rooms, however, often complain of headache and lassitude, and it appears extremely probable that such symptoms are due to pollution of the air with the unburned products of gas consumption; carbon monoxide being the most likely offender. Some recent experiments by the Manchester Air Pollution Board showed that a bunsen gas fire gave off two and a half times as much carbon monoxide as an exper-
artificial humidification has not been applied.

The deleterious effects noticed in connection with spinning processes are mostly due to working throughout the year under the influence of a constant high temperature. This obtains in mule spinning, ring spinning and doubling processes. A common working temperature in fine spinning rooms ranges from $80^\circ$ F. to $90^\circ$ F., that of rooms where low counts are being spun rarely exceed $82^\circ$ F. or $83^\circ$ F. under normal circumstances. Although temperatures are better regulated, and are consequently more even than formerly, the fact remains that workers are subjected daily, during the full working hours, to a much higher temperature than that existing outside. They are continually on the move, and sometimes, as when doffing or creel- ing, fairly vigorously, so that the heat-regulating mechanism of the body is constantly functioning. Occupation of this nature tends to the production of a certain amount of fatigue which, though not excessive and probably soon dissipated, appears to be sufficient to affect the bodily resistance against catarrhal colds and rheumatism, and thus to lead to the more fatal affections of the lungs and heart. It is therefore essential that means should be taken to facilitate evaporation of perspiration.

While work is proceeding it is extremely important that the best means for helping evaporation from the skin of the worker should be adopted. Although the air of the room is constantly being changed the motion so produced is not felt, so that the practice adopted by some firms of fixing fans on the shafting is commendable. The workers themselves are as lightly clad as possible, and have their feet bare. The men and boys wear trousers of cotton drill or light corduroy, with a shirt open at the neck and the sleeves turned up; the clothing of the women and girls is light, but on the whole not so satisfactorily designed to suit the conditions as is the case with males. The women workers should be provided with facilities enabling them to change into dry warm clothing before leaving the mills.

These conditions favour the outbreak of chloro-anaemia, especially amongst young women workers.

There should also be mentioned carver's fever, due for the most part to the action of vegetable dusts on the system of predisposed individuals, which may well be regarded as an anaphylactic phenomenon.

In 1924 the British Medical Inspectorate had an opportunity of studying afresh cases occurring among weavers affected with a cough. Similar cases had formerly been studied by Collis in 1912. The conditions described in the enquiry conducted by Bridge were similar to those reported in 1912, and it appeared that coughing was caused by fragments of mould and spores contained in the dust with which the looms were covered. Analysis of dust samples taken proved the presence of fragments of cotton fibre, of mycelium and of spores, especially penicillium.

Amongst the nervous diseases an important place is occupied by twister's cramp, studied in 1919 by Bridge, the Chief Medical Inspector of Factories in Great Britain. This disease, which attacks workers engaged in twisting, obliging them to give up their work and find another occupation, has been known for quite a long time. Cold certainly favours the outbreak of disease or rather of a state of rigidity of the fingers, which is, however, not the true cramp. The disease lasts for years and generally causes permanent incapacity for effecting the process of twisting.

In order to "twist" the yarn the worker takes up a position analogous to that of players of the guitar or banjo. The left hand especially is used for making knots on the threads which are repaired as required by the thumb and index finger. A clever worker can "twist" up to 2,000 threads per hour. This work brings into play a great number of muscles both of the forearm and of the thumb and first finger. It might be said that twisting and writing demand work by the same muscles, so that twister's cramp resembles closely writer's cramp. The danger is increased by the fact that the movements executed are limited to the small muscles.
The earliest symptom is pain at the base of the thumb and extending sometimes to the forearm. The region of the thumb is very sensitive and sometimes swollen. Whilst the true cramp is rare, there occurs, on the other hand, very frequently, a loss of muscular force and a restriction of movement. Fifty per cent. of the workers examined and reported as sick showed loss of the muscular mass of the thumb or of the small muscles (thenar region). It was, however, difficult, if not impossible, to prove that a true muscular atrophy was present, and it was likewise impossible to discover the influence of length of service on the outbreak of the symptoms which affected workers who had been engaged on twisting for periods varying from five to thirty-five years. It may therefore be concluded that there is no relation between the disease and length of service. Similarly it is difficult to say whether predisposing factors exist, for instance addiction to alcohol, since the disease was noted in the case of total abstainers and others with no previous records of disease.

Bridge suggests a double origin for this disease: first a cause analogous to that of all cramps represented by troubles of the nervous centres which control the movements in question, and secondly a local cause provoking oedema that a traction of the muscles used — chronic fibro-myositis.

The introduction some years ago of a machine for effecting the operation of twisting, which completely replaces manual work, leads to the hope that the symptoms in question will rapidly disappear.

Amongst workers engaged on combing the skin of the hand is often thin and in the interdigital space between the thumb and first finger especially it is thickened. This "heat" thumb, however, is a very slight lesion, which is particularly confined to novices in the trade.

A cutaneous eruption has been met with in workers harvesting and ginning the cotton (due to acarida in the cotton seeds) or amongst workers engaged in bale-breaking and in the blowing room (due to moulds).

Two very widespread symptoms are spinner's folliculitis and perifolliculitis due to the effect of certain lubricating oils (see articles "Petroleum" and "Shale Oil").

This lesion, described for the first time in France by Leloir (1888) and studied by Lefebvre (1889), the outbreak of which is favoured by high temperature, is usually situated on the uncov-ered parts of the body (arms, legs, face). It is usually found to be distributed symmetrically on the body, the feet and hands not being affected. Amongst novices in certain departments of the factory there is seen on commencement of work a rash which breaks out after a few days (Prosser White). This symptom rarely affects workers engaged in bale-breaking or in the blowing and mixing rooms. It is certain that this dermatitis (oil rash) is due to the action of the oils used, for it has been found that its incidence increases with increase in the amount of oil used, and especially if oils of inferior quality are applied. While, in fact, 45 litres of oil per week are used in the mule spinning mills, only 25 litres are used in the carding rooms and 9 litres in the ring spinning mills. In the mule spinning departments, the workers most affected are the sweepers, scavengers, roving hands, mule spinners and piecers.

Forms of dermatitis have also been met with amongst workers engaged in the workrooms for preparatory processes and in the dressing and dyeing departments. In the latter cases the cutaneous affections are caused by alkalis (soda, potash), alum, formaldehyde, etc., which makes the skin hard and leathery. The skin cracks readily and painful fissures are caused which become infected and often oblige the workers to quit their work. In the dressing departments it is the use of chloride of zinc, phenol, salicylic acid and salts of arsenic which set up the symptoms. In the dyeing departments the responsible products are alkalis, acids, metallic salts (iron, tin, lead, antimony, zinc, copper, etc.).

There should be mentioned, in passing, the bad habit of the majority of workers of putting the shuttle thread in their mouths. This habit of "shuttle kissing" may actually be the means of transmitting very serious diseases (syphilis, tuberculosis, etc.)—Watts.

It would appear that spinners' cancer so far as mule spinners are concerned can fairly be considered as having a definite relationship with the question of personal cleanliness and should therefore be dealt with under this heading.

The credit for bringing to light the special susceptibility of mule spinners to contract epithelioma of the scrotum is due to Mr. Southam and Dr. Wilson, two members of the honorary staff of the Manchester Royal Infirmary, who contributed an article on the subject to the British Medical Journal of 18 November 1922. They had examined the Infirmary re-
cords for a period of twenty years (1902-1922) and out of a total of 141 cases of scrotal cancer had found that 69 of the sufferers were mule spinners. They suggested that the soaking of the clothes with mineral lubricating oil together with friction between the body and the counter faller shaft of the mule carriage, whilst piecing, accounted for the causation.

The report of the British Medical Inspector of Factories for 1923 provides some interesting facts. Details collected by Dr. Henry show the occurrence of 145 cases of skin epithelioma among mule spinners between the years 1907-1923, of which 128 had necessitated treatment since 1918. In 93.1 per cent. of the cases the disease was scrotal and in 6.9 per cent. was on the forearm, wrist, left hand, left thigh or left foot. The earliest age of incidence was thirty-three years, and in over 90 per cent. the age of those attacked was over forty; the majority had spent all their working lives at cotton spinning. Of these cases, 47 had died from the disease (32.4 per cent.). 83 were alive at the time of investigation, though 5 were regarded as too advanced for operation, and in 13 the result was unknown.

The report of the Medical Inspector of Factories for 1927 contains 361 cases, as notified since 1923, 104 of which were fatal. Amongst these 361 cases, 268 were situated on the scrotum (74.2 per cent.), 38 on the arms (10.5 per cent.), 25 on the face and back of the neck (6.9 per cent.), 15 on the lower limbs (4.2 per cent.) and 15 on other parts of the body.

Of these 361 workers 107 had been in the trade from thirty-one to forty years, 104 forty-one to fifty years and 55 fifty-one to sixty years; 54 only had been in the trade from twenty-one to thirty years, 17 from sixteen to twenty years and 9 from ten to fifteen years; 9 workers had more than sixty years' experience of the trade and for the other 9 no information was available. A very detailed investigation into the incidence, probable cause and the clinical picture of this lesion of occupational origin was conducted in Great Britain by a special Committee which published its report in 1926. Many communications on the same subject were made by English medical experts at the International Cancer Congress (London, 1928).

In 1922 the English Registrar-General received notification of 32 deaths due to cancer of the scrotum, 19 of which (32.7 per cent.) affected spinners. In 1923 the fatal cases recorded amounted to 61, of which 20 (32.7 per cent.) occurred among the workers in question. The enquiry revealed that all of these victims had been in contact with mineral oils or pitch (in 1923 5 cases were workers in gasworks).

From some unpublished records of the Registrar-General, quoted by Dr. A. Leitch at the Annual Meeting of the British Medical Association, 1924, it appears that during the two years 1913 and 1914 scrotal cancer accounted for the deaths of 18 cotton spinners, during the years 1921 and 1922 for the deaths of 26 spinners, and during 1923 for 15. Although cancer of the penis is a much more common cause of death among the general population, not a single cotton spinner died from it during either of the two-year periods mentioned. As the above figures show an average annual death-roll of 11.8, and as there are over 23,000 adult mule spinners in the country, all males, Dr. Leitch points out that approximately one spinner in 2,000 dies each year from cancer of the scrotum. As regards site, the growth mostly chooses the upper part and front aspect of one side — generally the left. It starts as a papule, which becomes wart-like, spreads and breaks down into ulceration, the inguinal glands becoming involved in due course.

As regards causation it is now certain that the impregnation of the garments with lubricating oil is the main factor. Spinners make a practice of changing into clean working clothes every Monday morning, and there is no doubt whatever that towards the end of the week, the front of the trousers, both upwards and downwards from the line of the groin, exhibits a well marked oily patch. There are also other small patches to be found on each trouser leg, one over the knee and the other over the ankle.

The next question to decide is the manner in which these oily patches on the clothing are brought about. One must look to the mule carriage for the place of origin so that the first consideration is the various oiling points which may be at fault. There are two faller shafts close together and running parallel to one another, the one in front being known as the 'counter faller shaft'. These shafts run in double ring bearings, one for each, situated about 4 ft. apart, the top of each bearing being provided with a lubricating hole. These bearings do not require frequent lubrication, about once a month being regarded as sufficient, but if the oiling is done carelessly some of it will, on these rare occasions, get on the shaft. In fine
spinning rooms it is certainly not usual to find the faller shafts oily, but it is not uncommon to find them slightly soiled at mills where low counts are being spun. In the latter case, however, the latter may get its oil from the spinner's trousers. These parts certainly get wiped down with oily waste during cleaning, but this only takes place once a week as a rule, and twice a week in the less dangerous Bolton factories. There are two lubricating points for each spindle and these require considerable lubrication. The foot of each spindle is fitted into a bearing on the bottom spindle rail which is oiled every morning. Each spindle receives support, near its centre, from the top spindle rail through which it passes; on the top of this rail, for its whole length, there is a long shallow trough and thus provides with round holes corresponding to every spindle. Just before starting for the morning and afternoon spells, the spinner runs the spout of his oil can along the brass trough and thus provides it with a shallow stream of oil. Some of this oil runs down the spindle and gets on to the spindle wharves; but most of it, as soon as the machine is started and mainly during the outward run of the carriage, is scattered as a spray by the rapidly revolving spindles. For some minutes, on two occasions during the day, the spindles are centrifugalised, but as these parts of the oil runs on to the spindle wharves; but most of it, as soon as the machine is started and mainly during the outward run of the carriage, is scattered as a spray by the rapidly revolving spindles. For some time after starting it requires very heavily at the front of the carriage, and a good share of it falls on to the front sloping cover of the carriage whilst it is running in the same direction as the spray. The oil is soon dissipated, not a speck appearing on a clean sheet of cardboard, hung on to the counter faller shaft, half an hour after oiling had taken place. The spinner certainly gets the benefit of this spray for several minutes, on two occasions during the working day, and on the average it will strike him, as shown by card experiments, about the groin and upper part of the thigh. He can easily get enough this way to account for the oily patch. The oil which runs down the spindle on to the wharve, together with that in the bottom bearing, is also centrifugalised, but as these parts of the spindle are almost always covered none of it gets directly on to the spinner. It catches the covering boards and runs down behind, some of it emerging between the top and bottom cover, but most of it dripping down from the lower cover. The latter gets on to the trousers (particularly the left leg), and as the carriage is coming into contact with the lower cover when piecing; the former, together with the spray which has dropped into the top cover, oils the garment at the knees. The broad, even patch is brought about by capillary attraction, as is the implication of the shirt.

The next consideration is the pressure and friction to which the top of the scrotum or the left side is subjected during piecing. When a thread breaks, the spinner or piecer follows up the carriage to the end of its inward run and if the break is in the roving, he carries it through the draft rollers; he picks it up with the spindle end during the next inward run. He is leaning against the faller shaft when reaching up to the creel for the bobbin end, and by the time he is getting this into the rollers the carriage has started outwards. At this period he has to lean forward over the shaft and at each starting period owing with his left hand, he stands on the left leg and maintains his balance by raising the right leg. As piecing is done with the left hand, a similar stance is adopted during this part of the double process or of course when the break is in the draft rollers. Some of the oil runs on to the thigh and abdomen in the neighbourhood of the groin and not the scrotum. Nevertheless, it is highly probable that friction does play some part in helping forward the development of this malignant growth. The spinner is continually on the move, up and down his mule-gate or backwards and forwards with his carriage, which must mean a continuous rubbing action going on between the oily scrotum and its oily surroundings. In mills spinning the coarser counts the minder moves about more and quicker than in fine spinning mills, owing to the longer stretch taken by the carriage and the less time it utilises in doing it. Whilst this means more friction it possibly means more oil as well, if greater attention has to be given to the mule carriage at each starting period owing to the greater number of breakages at such times. This speeding up may thus have something to do with Dr. Henry's cases arising in Oldham and only 21 in Bolton.

Another factor for consideration is the high temperature and the continuous coming into contact with the lower cover when piecing; the former, together with the spray which has dropped into the top cover, oils the garment at the knees.

The broad, even patch is brought about by capillary attraction, as is the implication of the shirt.
The next point is the type of oil used for lubricating purposes. Before mineral oils came into vogue the practice was to use sperm, lard and neat's-foot oils and to some extent castor oil and colza oil. Henry states that shale oil was introduced about 1850 and American petroleum oil about 1864, and that, towards 1872, these oils were being used as components of spindle oil; also that Russian oil was first imported about 1880, Rumanian oil about 1900 and Persian oil about 1909, and that all these were used for this class of lubricating oil before the war. During the war Scottish shale oils naturally came more into use for lubricating purposes. Oil refineries have their own private formulae for mixings, but there is no doubt that the bulk of the oil sold for lubricating spindles during the past forty years has been principally made up of natural mineral oil.

There must now be considered to what extent mineral lubricating oil possesses carcinogenic properties, and fortunately there is some very definite information on this point. Well-authenticated cases of epithelioma have occurred among the workers in the mineral oil refineries of Czechoslovakia, Galicia, Silesia and Hungary, and Dr. Scott, of Broxburn, has published an account of 65 cases of paraffin cancer occurring among workers in the Scottish shale oil refineries. All the cases appear to have arisen from the working among the crude products, with the exception of some of those reported by Dr. Scott, and the scrotum has been the part mostly affected. Scott found that several cases of scrotal cancer occurred amongst men who were dealing exclusively with the more refined oils. Dr. Archibald Leitch, at the 1922 meeting of the British Medical Association, provided definite proof that Scottish shale oil was carcinogenic with mice, and in his 1924 contribution previously referred to he gave details of experiments which proved that these animals develop epithelioma as the result of continuous treatment with petroleum mineral oils (see article "Petroleum").

Pathology relative to women workers also calls for attention. According to a report of Hirsch, the German Sickness Funds in 1907 included amongst their members a percentage of women amounting to 21.6, in 1913 to 31.2 and in 1924 to 35.3. The sickness rate was higher for the women than for the men, being 48.1 for the former and 28.7 for the latter. Days of sickness for the women were 40 per cent. higher than the average for all members. As regards especially women workers in the textile industry, for 100 cases of pregnancy there occurred a percentage of 19.5 premature births and miscarriages amongst the spinners and 18.4 amongst the weavers.

The effort necessitated by the different operations for pregnant women causes distension of the ligaments of the genital system which explains the incidence of plosis of the genital organs. Walking and standing favour, besides, derangement of the circulation in the lower limbs (varicose veins, phlebitis), in the pelvis (risk of uterine haemorrhage), and prepare the way for renal lesions. These troubles also affect the abdominal muscles, rendering delivery difficult and therefore constituting a risk for the mother as well as for the infant. There should be recalled in addition the risk for pregnant women connected with psychic derangements (see article "Women's Work").

Hygiene

In the preliminary dealing with the cotton, dust can be very successfully kept out of the atmosphere by feeding the cotton in bulk directly into the hopper of the bale breaker and by transferring the separated tufts to the openers through exhaust ducts. The dust removed through the cages of openers and scutchers is carried away by ducts placed beneath the floor, and is deposited in a chamber fitted with an air shaft of sufficient capacity to prevent the creation of positive air pressure within such chamber.

Every factory is now provided with an exhaust system, which in most cases appears to be effective. When cases of asthma still arise they are found to be due to weakening of the exhaust. One finds attacks of asthma still occurring among men engaged in emptying the dust chambers under the cards, and this can be effectively dealt with by a suitable respirator.

The most practical is a light aluminium type, the rim of which can be
manipulated to fit the face quite closely, the dust being caught by a piece of lint replaceable at will. These respirators are also used by strippers when there is something wrong with the exhaust.

The general result of these improvements is shown in the diminishing death rate from bronchitis and in the circumstance that strippers do not now leave their trade at forty to forty-five years of age.

The general air of the card room should be kept clear by a well-arranged method of mechanical ventilation. As in all mechanical systems, care should be taken to secure the entry of a sufficient quantity of fresh air to balance the pull of the extraction fans and also to make certain that the incoming air does not reduce the temperature of the room below 60° F., the agreed minimum.

To obtain good results in spinning mills it is essential to cool the air in a compressed state by causing it to pass over cold water pipes in the form of serpentine coils in order to condense the humidity of the atmosphere before it enters the compressed air reservoir (Burnham, 1924).

Ventilation of cotton spinning mills has as its object elimination of excessive temperature and of impurities due to respiration, to material handled and to running machines. On the other hand, the object of humidification is to render the textile fibre sufficiently damp and to cool the air of the workroom. This double purpose is achieved by renewing the air of the room and at the same time effecting evaporation in a suitable manner. It is thus possible to ventilate, humidify and cool the atmosphere.

The combined problem of humidification and of cooling consists in sending into the workroom a sufficient quantity of air to evaporate the given quantity of water estimated to be necessary. Fuller details in regard to this problem will be found in the article "Textile Industry". Here it is sufficient to mention that modern technical progress enables factory managers to install systems under which the amount of air and water introduced (separately or otherwise) is so accurately calculated that it can be adequately adapted to the different industrial requirements.

In summer the ventilation (provision of fresh air) should be sufficient and capable of regulation at will, according to requirements, amounting to six or seven renewals of the atmosphere per hour. In winter more restricted ventilation as required by the condition of the external atmosphere should be possible. The degree of humidity in the workroom should be that most suitable for the process of manufacture in progress. The air should be purified constantly and in summer cooled to a certain degree. The heating of the workrooms should be conveniently arranged and combined with the ventilation. Even during great cold, for instance — 20° C. outside, the atmosphere in the workrooms should be +18° C.

It has been seen already that the humidity and temperature rates in certain operations of cotton spinning may be fixed as follows: carding, 22° C. and 55 per cent.; mixing, 22° C. and 60 per cent.; preparation, 23.8° C. and 75 per cent.; mule spinning, 23.8° to 26.5° C. and 50 to 54 per cent.; ring spinning, 23.8° to 25.6° C. and 55 to 60 per cent.; weaving, between 22° and 26.5° C. and 60 to 85 per cent., according to the qualities of the material produced.

An enquiry into humidification conditions in Indian cotton mills was organised in 1921 and the conclusions of the investigator (Maloney) were issued in 1923.

As regards lighting in cotton mills, it is sufficient to recall that the lighting values vary naturally according to the work engaged in in the different departments. Thus, for example, an average value may be fixed at 15-25 lux for the packing department; 20-40 lux for the spinning mills, for twisting, etc.; 20-60 for weaving; 20-40 for dyeing; 80-120 lux for very fine processes; 5-15 for lighting of alleys, etc.

Personal hygiene. — All establishments in the Lancashire cotton towns are fairly well provided with public baths in the neighbourhood, and the prospective operative during his or her school career is well trained in the matter of bodily cleanliness by being compelled to join a bath parade once every week. This regular cleaning is kept up to some extent after entering the mill, but the general tendency is to lapse as time goes on. Where there are welfare supervisors the tendency may be checked to a considerable extent, and a favourite method is to promote interest in swimming by forming clubs and getting up inter-mill competitions. The older hands, unless they have baths at home, appear to be very irregular with their bodily washing.

The greatest need for regular baths arises amongst those working in the winding and doubling rooms. They necessarily perspire a great deal and, during their work, dispense with
shoes and stockings. These operatives should each have two baths per week, and those in the other parts of the mill should not be without the weekly bath. The only way to cater for the older workers who have no home facilities is to provide a certain number of bath-rooms or douche rooms at the mill, and this solution is being seriously considered by some millowners. As previously stated, all mills should have sufficient and suitable lavatory accommoda-tion and foot baths or troughs for cleansing the feet and legs. As a preventive of dirty feet, as well as a pro-tective measure against splinter wounds, some firms have adopted canvas shoes with hemp soles for workers in spinning and doubling rooms.

As regards protective measures it is not at all likely that anything can be done to change the character of the lubricant, so that efforts must be made in the direction of preventing the oil coming into contact with the clothing. For the latter purpose there is something to be said for the protective apron. Rubber would be no use, but an apron treated with linseed oil in the tarpaulin manner, or treated with cellulose as suggested by Leitch, might be helpful. Women piecers frequently wear a short leather apron to save their clothes from wear, and this certainly seems to collect a considerable amount of oil. In the opinion of Leitch, it would not be difficult to provide a gummed leather apron, with a top spindle run, which would block the spray of oil from this source. It is, however, probable that the most effective preventive would be the frequent use of soap and water. A suspensory bandage would be of some assistance in supporting the relaxed cotton and wounds and would minimise friction, though it would be no real use unless repeatedly washed.

The British Committee (1926) recommended research with a view to discovering a harmless lubricating oil; the use of a mule-carriage which does not project drops of oil or of a protecting screen for the older machine; periodical medical examination of the workers; instruction of the worker as to the risks run; application of measures of personal cleanliness, etc.

A sufficient suitable and separate latrine or closet accommodation for both sexes is not always present in all factories. Conveniences should be well lighted and ventilated and kept clean, and should not communicate with any workroom except through a ventilated space. They should be under cover, partitioned, and in the case of those provided for the female staff, bath doors and fastenings. Clean, well ventilated cloak-rooms with hygienic metal lockers, perforated at top and bottom and in front, and capable of being sufficiently heated to dry wet clothing, are a necessity for all workplaces, and particularly so for cotton spinning mills. The high temperature in spinning and doubling rooms makes a change of clothing necessary. As it is imperative that the changing room should not be far removed from the workroom. Separate rooms should be provided for each sex on each floor, and those in the spinning and doubling departments should be fitted with wash-bowls, footbaths and bathrooms, and hot and cold water provided. In the other departments a less extensive provi-sion is necessary. The practice occasionally followed at present of changing clothes behind mule creels should not be permitted.

Adequate provision of the accommodation above described would materially diminish the excessive liability of cotton operatives to catarrhal colds, rheumatism and its after-effects, and bronchitis, and the outlay involved would bring a valuable return in the increased health and comfort of the worker, and assist in attracting a better type of worker. The industry requires a good standard of intelligence, health and physique, but the amount of discomfort generally involved in a cotton mill results in the fact that the industry attracts only a lower-scale type of applicant.

Selection of operatives by physical standard: welfare.—The calling in of the doctor to testify to the physical aptitude of children and young persons for work in cotton mills was one of the early phases of the series of efforts towards improving the well-being of textile operatives, and the welfare movement in Great Britain is probably the most important of its later phases. Great success has attended co-operation between the certifying surgeon and the welfare supervisor. The former makes his examinations in the welfare department and the supervisor attends to carrying out his instructions and recommendations, and in some cases a more detailed examination, with card indexing of results and even re-examination, has been instituted. The welfare department is responsible for the maintenance of first aid and ambulance equipment, and may request the certi-fying surgeon to examine certain operatives complaining of symptoms having relation to the nature of their employment. A useful development of these activities would be examination of employees returning to work after
two or more weeks' absence and the keeping of a record of all absences due to sickness exceeding three days' duration.

The practice of allowing young workers to work for several weeks as learners without pay in order to qualify for the occupation of piecer is very bad from this point of view.

The cotton processes generally do not call for excessive muscular effort, but demand on the other hand a considerable amount of sustained effort, workers being mostly on their feet all day, and being required to execute a series of complicated movements and keep a constant watch over the machinery under their charge. A fair average physique, free use of limbs, good eyesight, and a proper degree of intelligence are therefore required.

Girls should wear caps to eliminate the risk of having their hair caught by machinery and they should be prohibited from wearing rings other than plain rings on their fingers, as they have been known to prevent the hand getting free from cleaning waste dragged into the pulley or gear.

Applicants who are undersized, deformed, suffering from malnutrition, marked heart affection, advanced anaemia, chorea, epilepsy, deaf-mutism, discharging lupus, suppurating glands, mental defect, corneal opacity, or advanced myopia, should be excluded, and such defects as definite signs of tubercular phthisis, otorrhoea, pediculosis, hernia, moderate anaemia, skin affections, conjunctivitis and refractive errors of vision curable by glasses should be rejected until cured.

Monocular vision that cannot be corrected by glasses renders an applicant unsuitable except for set-dragging or warehouse work. The humidity experienced in spinning and doubling rooms is apt to lower resistance to influenza, catarrh and rheumatism, and beginners should be free from rheumatism and enlarged tonsils or signs of bronchitis and also from valvular disease of the heart. Mule spinning demands perfectly normal binocular vision. Accommodation might enable the worker to carry on for a time, but would ultimately result in strain.

Blowing room and card room workers, being susceptible to respiratory disorders, should be recruited from workers with sound nose, throat and lungs. The high temperature in the speed, frame and drawing rooms makes predisposition to bronchitis, rheumatism, influenza and catarrh a disqualifying factor for these processes. Winding, reeling and beam ing, being the healthiest processes, may be recommended for those unfit for work in the other departments. Applicants suffering from respiratory affections, blepharitis, and anaemia should not be admitted to work in the gassing room. For set dragging, bodily strength and a sound heart are required.

Industrial welfare, as it is known in England, is being well taken up by Lancashire cotton spinning firms; indeed, the two large amalgamations in the industry have both adopted it as a definite part of their administrative policy. One of these bodies has thirty well-trained lady supervisors allocated amongst the various associated establishments, some concentrating their energies on one particular factory and others dividing their time between two factories. At a considerable number of the mills arrangements have been made with the certifying surgeon on somewhat similar lines to those previously mentioned.

It is obvious that cotton mills, particularly when situated in crowded towns, have very little room over and above what was planned out for specific purposes when the building was designed and, in a very large number of instances, have no land available for extensions.

These factors make it extremely difficult to meet many welfare requirements.

In the matter of location, the rooms should be easily accessible from all directions and from all floors. They should therefore be situated close to the main stairway and to a hoist, and be either on the ground floor or, at the highest, on the first floor.

It is certainly an economic gain, both to the firm and the individual, for carious teeth to be either filled or extracted, so that the possibility of instituting a dental clinic on the premises should not be overlooked. Provision for the correction of defective eyesight should also be made.

Legislation

The work of women as well as that of young persons under eighteen years of age is prohibited in France in workshops for bleaching and washing of cottons by means of carbon disulphide.

In Spain boys under sixteen and women under twenty-one are excluded from the manufacture of cotton blankets and cotton-wool in workrooms where cleaning and carding are effected. They are excluded from cleaning, beating and carding of
cotton in factories where adequate devices for dust exhaust have not been installed. In Italy boys under fifteen and women under twenty-one are excluded from beating, carding and cleaning of cotton where good dust exhaust systems are lacking (even employment in the same workroom or on other machines or other processes is prohibited).

The British Order of 21 December 1911 relative to textile and cotton factories dealt with humidity and ventilation. A short Act, known as the Factory and Workshop (Cotton, Cloth Factories) Act, 1911, contains regulations which came into operation on 15 May, the regulations under the previous Act of 1911 being repealed. Under this new Act the following regulations take effect:

Artificial humidification must cease when the wet bulb temperature reaches 72.5° F., instead of at 75° as formerly, or when the scheduled relationship between the wet and dry bulb readings is exceeded; if average readings exceed 80° wet bulb, work must cease until this limit is regained; the minimum temperature permitted is 50° dry bulb for the first half-hour of the day, and 55° subsequently. Top lights are to face between north-east and north-west; if the average of the readings of the hygrometers reaches 72.5° wet bulb, ventilation is to be continued during dinner hour, or for two hours after work finishes, as the case may be; cloakrooms are compulsory for "humid" sheds built after 2 February 1898, and for "dry" sheds built after 1 January 1928; defects in the working of appliances must be reported, and only individuals duly authorised may interfere with them or with hygrometers. Regulations concerning steam, pipes, boilers and flues, whitewashing and hygrometers have not been altered.

In Egypt there are legislative provisions for the protection of children occupied in ginning cotton (Order of 3 July 1927, amended by that of 5 May 1928).

The Indian Factory Act of 24 March 1911, amended in 1922, prohibits (section 20) the employment of women and children on compressing of cotton by machinery (unless bale-breaking machines are completely separated from the workshop in which other machines are fed). Section 52 of Act No. IX, of 5 March 1923, relating to factories, contains provisions as to the medical examination of children. Every certifying surgeon must visit those factories in his area which employ children. The following conditions: textile industry: six annual visits where the factory employs 150 children or under; twelve visits where over 150 are employed. The Act relative to cotton factories was amended by that of 18 March 1925. Regulations of 17 October 1922 issued in the Punjab provide, in section 23, measures relative to ventilation of workshops, and in section 42 measures dealing with the prevention of accidents during cotton ginning.

In Norway the Royal Order of 30 October 1919 contains hygienic measures for the textile industries: daily collection of waste; washing of clothes; distribution of clean material for machine cleaning; periodical cleaning of windows, etc.

In the Netherlands young persons engaged in weaving sheds have to be submitted to compulsory medical examination.

For the Portuguese Colonies (Angola), Decree No. 1199 of 28 July 1926 contains hygienic and safety measures relative to cotton factories.

A compulsory Russian Order, dated 6 November 1925, enumerates safety measures for cotton factories.

Legal measures have also been provided in regard to home work (for instance in Czechoslovakia, 1919), for the length of the working day (Spain, France, Holland, 1920; Argentina, Italy, etc., 1923).

As regards occupational diseases, Dutch legislation alone enforces compulsory notification of cases of pulmonary disease as well as mercury poisoning (printing of textile materials) affecting workers in the textile industries.

Great Britain provides compensation for twister's cramp (see also articles "Occupational Diseases — Nervous System" and "Textile Industries").

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Cresols, Cresylic Acid


Cresols are the homologues of phenol. This name is borne by three isomeric oxytoluenes \((C_6H_5(CH_3)OH)\) which are present in abundant quantity in the middle oils of ordinary tar and wood tar (see article "Coal tar").

Crude cresol (cresyl oil or cresylic acid) when freshly prepared is an oily liquid (density, 1,055) with a smell like creosote. It is soluble in alcohol as well as in alkaline hydrates with the formation of corresponding salts (cresylates).

Pure cresol (tricresol) obtained by rectification of crude cresol with alkalis and thin acids is a colourless or yellowish liquid with a smell like cresosate. Its density is 1,045-1,050; it boils at 145-205° C. and dissolves completely in a 10 per cent. solution of sodium hydrate.

**Production**

Crude cresol is prepared by fractional distillation of the phenolic tar oils and constitutes the portion coming off between 180° and 204° C. Pure cresol is obtained either by purification of crude cresol or from the amino-derivatives as a starting point or the corresponding sulphonic acids.

The o-cresol is obtained from o-toluidine or o-toluol sulphonic acid. The m-cresol is obtained by fractional distillation of crude cresol. The p-cresol is obtained from p-toluidine as a starting point or from p-toluol sulphonic acid.

**Uses**

Crude cresol is used as a disinfectant and antiseptic instead of phenol and serves for the preparation of numerous products, among which mention should be made of cresol soap or saponified cresol, creoline (prepared with resine-caustic soda and crude cresol). In solution it is used as a disinfectant, antiseptic and deodoriser, especially for closets, urinals, floors, etc. Lysol, an antiseptic disinfectant differing from creoline by its solubility in water, is a concentrated solution of crude phenol. It is used as a disinfectant for wounds, for diseases of the skin especially in animals, to cure plant diseases, etc. Many analogous products are sold under various names: "Saprol", "Carbolineum", "Solutol", "Cresoline", etc.

Pure cresol is used in much the same way as the crude material as well as in the preparation of artificial resin. Its sulphonic derivatives are used in the preparation of artificial tanning substances.

The o-cresol is used as a bactericidal agent and in the preparation of caoutchouc and artificial resin and sulphur colours. The sodium salt of its nitro-compound is "antinonnine" (anticyryptogame) and a solution of diorthonitrocresolate of potassium constitutes "antiparasitine". The m-cresol is used as an antiseptic and in the preparation of synthetic perfumes (amber, musk); the p-cresol in the manufacture of artificial rubber and of certain synthetic organic colours. Its methyl ether, the p-cresylate of methyl, is a liquid of pleasant smell which enters into the composition of the artificial essence of ylang-ylang.

Cresol also serves in the preparation of numerous compounds used in medicine as anthelminths or as medicaments (antipyretics, anti-rheumatic medicines).

Cresotinic acid should also be mentioned: it is used in medicine and in industry in the preparation of synthetic organic colours, artificial tanning substances by condensation with formaldehyde, and sulphuric acid.

The nitro-cresols are obtained by the action of nitric acid on the cresols and according to the degree of nitration, the mono-, di-nitro- and trinitro-cresols are obtained. The trinitro-metacresol, which is made from cresol as a starting point, just as picric acid is from phenol, is used as a disruptive explosive for charging projectiles ("cresylite").

The amido- or amino-cresols are the various aminated derivatives of the three cresol isomers which can be obtained from their respective nitro-compounds. Soluble in water, they are more so in alcohol and ether. They
are used especially in the preparation of synthetic organic colours.

**Sources of Danger — Toxic Action**

In the course of the preparation of cresol, risk lies in the substances handled or in those which are given off. But the greatest risk occurs in the use of cresol and preparation of products containing cresol. The toxic effects resemble those of carbolic acid, except that they are less severe.

**Pathology**

Contact with cresol causes redness of the skin, a sensation of heat and itching; small vesicles, ecchymoses, eczema, and even burns develop according to the concentration of the substance, the duration of contact with the skin, etc.

Brown staining of the face has been described. If splashes get into the eyes, the workman is attacked by a very painful conjunctivitis.

A chronic irritation of the skin, folliculitis, and warty growths with pigmentation of the shed skin are common. Papillomata are found on the scrotum which proliferate and degenerate easily. Among workpeople employed for a long time with hot solution of carbolineum and having their clothes soaked in the liquid, folliculitis with epithelial warty and extremely itching proliferation occurs on the uncovered parts.

In workers handling boring oils containing such impurities as phenols, cresols, etc., eczemas have been found which, e.g. in women, are commonest on the neck or head from contact with the oily hands.

Among general symptoms, weakness and loss of flesh are reported. Absorption of cresol may set up a parenchymatous lepatitis, haemolysis, nephritis, and secondary lesions of the heart and brain. Koelsch could not find ill-effects from the inhalation of cresol vapour.

Dinitro-cresol, \( \text{C}_6\text{H}_2(\text{NO}_2)_2\text{CH}_3\), OH, employed as a yellow colouring matter in the form of potassium or ammonium salts (Victoria yellow, orange yellow, aniline-orange), produces a yellow discolouration of the hair or skin with feeling of heat, itching, confluent vesicles, and increase of temperature.

Trinitro-cresol (and especially its ammonium salt) is used, like trinitro-phenol, as an explosive and sets up analogous lesions. Para-nitroso-cresol is relatively harmless and has caused very few cases of skin irritation.

The cases of dry skin, rhagades, etc., produced in tanners by the use of new products for artificial tanning ("Syn-tan", "Marytan", "Neraldol", etc.) are explained by the fact that cresols and analogous products are the starting point in the production of these tanning matters.

For measures of hygiene and legislation, see the article "Phenols".

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**Cyanogen and its Compounds**


**Technical Data**

Cyanogen, formula \( \text{CN} \), is a colourless gas with a penetrating smell of bitter almonds. Its density is 1.806. It burns in the air with a reddish flame. It is soluble in water, but more so in alcohol; it is absorbed by ether and solutions of salts of silver and mercury, by iodine, alkaline solutions and ferro-ferric salts, which are an antidote. It is found in small quantities in gas from blast furnaces, in illuminating gas and other industrial gases. It is given off during the electrolytic decomposition of metallic cyanides. It is prepared in laboratories by the reaction between solutions of cyanide of potassium and cupric sulphate. It has no practical use.

A large number of derivatives of cyanogen, characterised by the presence of the group \( \text{CN} \), are of practical importance.

In addition to hydrocyanic acid and cyanamide of calcium (see those articles) should be borne in mind cyanic acid and the only slightly toxic cyanates, cyanuric acid, and in particular the following products:

* Chloride of cyanogen (Manguinite), \( \text{CNC} \), is a gas which liquefies readily. In practice it is found as a highly volatile liquid, easily changed into a solid body in the form of yellow needles, which melt at over 140°C.; its fumes are exceedingly irritating, causing cough and lachrymation.

* Bromide of cyanogen is a toxic gas, as is also the iodide of cyanogen and cyanohydrogen.

But the most important derivatives of cyanogen are the cyanides, or salts of hydrocyanic acid, some of which are very poisonous and must be manipulated with the greatest precaution.

* Cyanide of potassium exists as white or yellowish crystals, with a sickly and suffocating smell of bitter almonds. It is deliquescent in air and in light; it is very soluble in water, but much less so in alcohol.

* Strong or even such weak acids as carbon dioxide in the air displace the hydrocyanic acid of cyanides, and this reaction
is quickened by heating. The commercial product contains, according to its purity, from 98.5 to 99.5 per cent. of pure cyanide; normally it contains 40 per cent. of cyanogen and 40.3 per cent. of hydrocyanic acid. The impurities consist chiefly of carbonates, sulphates, chlorides and cyanates.

It can be obtained commercially by heating ferrocyanide of potassium, which is itself obtained originally from organic waste, or by melting it with potash. Among the many other reactions used for its manufacture may be mentioned the following:

1. Treatment by heat of ammonia with sulphide of carbon. A sulphocyanate of ammonium is formed, which is changed into sulphone cyanate of potassium by potash. This is in its turn changed, under the action of lead oxide, into cyanate, which is finally reduced to cyanide by charcoal at a high temperature.

2. The passage of ammonia gas over heated potassium cyanide of potassium, which is formed is then changed into cyanide by coke.

3. Heating calcium cyanamide with potash and charcoal.

4. Treating trimethylamine, which is obtained from the waste liquids from refining sugar beet, by passing it into a tube kept at 1,000° C., when it becomes decomposed into methane and hydrocyanic acid which is fixed by potash.

5. Treatment under special conditions of a concentrated solution of sulphocyanide of potassium by nitric acid. Sulphuric acid and hydrocyanic acid are formed which are absorbed by potash.

Sodium cyanide, NaCN, shows the same characteristics as the preceding salt. It contains normally 53.06 per cent. of cyanogen and 54 per cent. of hydrocyanic acid. It is obtained by the same methods as those employed for the preparation of cyanide of potassium, by substituting sodium compounds for potassium compounds.

Among the numerous metallic cyanides should be mentioned:

Silver cyanide, AgCN, a white powder which is insoluble in water, soluble in ammonia and alkaline solutions; it is prepared by precipitating a silver salt by cyanide of potassium.

The double cyanide of silver and potassium, KAg(CN), which exhibits the same characteristics; it is prepared under the same conditions.

Cyanide of gold, Au(CN), which is usually employed combined with potassium to give the double cyanide of gold and potassium, Au(CN), KCN·H₂O; it crystallises in colourless or yellowish scales, soluble in water. Acids easily decompose it, setting free hydrocyanic acid.

Cyanide of mercury, Hg(CN), a salt composed of white, prismatic crystals which are slightly efflorescent; it is soluble in cold water, more so in warm water, and not at all in alcohol. Heat decomposes it, with the liberation of cyanogen. It is prepared by making oxide of mercury react on hydrocyanic acid or Prussian blue.

Oxy cyanide of mercury, Hg(ClCN), HgO, is a white or yellow powder, soluble in seventy-five parts of cold water and more so in boiling water. When heated gently it swells into a grey mass which, as the temperature is increased, volatilises without leaving any residue.

The cyanides of copper, bismuth and zinc are of little importance.

Cyanide of benzyl bromate, C₆H₅BrCN, is a volatile product which is extremely poisonous and is manufactured from several toxic products: chloride of benzyle, cyanide of sodium and of bromium.

Cyanide of diphenylarsine, (C₆H₅As)₂CN, used as a poison gas, is made by treating chloride of diphenylarsine with cyanide of sodium.

The cyanides of iodine, ethyl and methyl are of little importance. On the other hand there should not be overlooked platino-cyanide of barium, Pt₂CN₂, Ba₄H₂O₄, in the form of prismatic crystals of a lemon yellow colour, soluble in thirty-three parts of water; it is used for the preparation of radioscopic screens and may be replaced by the platinocyanides of lithium and rubidium.

This group, consisting of the ferri- and ferro-cyanhydrines and their salts, is especially remarkable in not exhibiting any of the reactions of iron or the derivatives of cyanogen.

The ferricyanides, or salts of ferri-cyanhydric acid, are derived from the combination of a molecule of ferric cyanide with three molecules of hydrocyanic acid which gives ferrocyanhydric acid, H₃Fe(CN)₆. They are prepared by treating ferrocyanides with an oxidising agent, such as chlorine or bromine. The alkaline and alkaline-earth ferrocyanides are insoluble in water, but the others are not.

Ferricyanide of potassium occurs in the form of rhomboidal prismatic crystals, of a rose red colour, with greenish reflections, without smell, soluble in water and insoluble in alcohol. It is prepared by passing a current of chlorine into a solution of ferrocyanide of potassium, or, instead, by submitting this solution to electrolysis. It is used in dyeing, as an oxidising agent, for printing cotton materials; as a mordant, for printing with aniline black and with alizarin; in chemical analyses; and in making blue fruit papers.

Ferrous ferricyanide (Turnbull's blue) is obtained by precipitation of a solution of ferricyanide of potassium with a ferrous salt.

Ferro cyanhydric acid, H₃Fe(CN)₆, which is prepared by acidulating a solution of ferrocyanide of potassium with hydrochloric acid, is used chiefly for printing blue colours on fabrics.
The alkaline and alkaline-earth ferrocyanides are soluble in water; the others are not, but are so in a solution of hydrochloric acid. The solutions give with ferric salts a precipitate of Prussian blue.

Ferrocyanide of potassium, \( K_2[Fe(CN)_6] \), exists in hydrated crystals, which have a rather brownish colour and are transparent, soluble in water and insoluble in alcohol.

It is prepared by several methods:

1. By the direct calcination with potash of such organic materials as horns, wool, blood, skins and other refuse from abattoirs. The cyanide of potassium which is formed is collected by washing with hot water, and transformed into ferrocyanide by digestion with ferrous oxide or sulphide of iron. The mass is next crushed and then treated with hot water. Crystallisation occurs on cooling.

2. The mass from the purification of illuminating gas, which retains the cyanate compounds of gas (see article “Gas Works”) is washed in order to remove the ammoniacal salts and then mixed with lime. It is washed again to remove the ferrocyanide of lime formed, which is transformed into ferrocyanide of potassium by adding potassium chloride or carbonate.

3. The ferrocyanide may also be obtained by treating an aqueous solution of cyanide of potassium with ferrous oxide or sulphide of iron, or by heating sulphocyanate of potassium with powdered cast iron and then washing the mass.

Ferrocyanide of potassium is used for preparing Prussian blue; for dyeing silk, acting as an oxidising agent; for printing inks, coloured paper, and in printing on materials. When mixed with certain yellow substances it is used in the manufacture of green colours, such as “cobalt green” and chromium green.

**Sources of Danger**

**During the Manufacture of Different Products**

Dangers may arise either from the crude materials or the intermediate products or the manufactured products.

It is thus that workshops for the manufacture of cyanide, ferrocyanide of potassium and of Prussian blue, by the calcination of animal materials, may give rise to the following nuisances: smells from the animal materials used; exhalations; waste waters which are very prejudicial to health; in addition to possible effects from the toxic products made or used.

**During the Use of Various Products**

Cyanides of potassium or sodium (the latter being more and more frequently used as it is less costly) are used in the following operations and industries.

(a) Extraction of gold and silver; silver and gold electro-plating, where cyanides of silver or gold are used, or the double cyanides which are better.

(b) Gilding by the amalgam method; and cleaning gold articles and precious stones by steeping them in a solution of cyanide of potassium, and then rinsing and washing in a solution of Panama wood.

(c) Soldering metals. Metallurgy; cementing by cyanide. The article, after preliminary heating in a furnace or forge, is plunged into a vat containing cyanide.

(d) Hardening of metals, coppering, zincing, and bronzing.

(e) Elimination of marks of silver nitrate in the operations of silvering mirrors and hair dyeing — cyanide of sodium when used for the latter purpose may penetrate into the system.
by means of wounds or cutaneous abrasions, and for this reason this dangerous practice has been given up.

(f) Photography, where the cyanides are now actually replaced by hypo-sulphate of soda.

(g) The preparation of hydrocyanic acid either in laboratories, or for the fumigation of plants in order to destroy parasites, weevils and caterpillars, or for riddling houses or ships of vermin, e.g. deratting. It has been used in some places to kill cats and dogs which have been impounded.

(h) Preparation of other derivatives of cyanogen, and notably of such organic derivatives as nitriles. The chloride, bromide and iodide of cyanogen, used during the war as poison gases, are used at the present time for the destruction of insects.

It must be remembered that chloride of cyanogen, cyanide of benzyle bromate, and cyanide of diphenylarsine have also been used as poison and lachrymatory gases in war.

The use in medicine must be noted, either for medicinal purposes or as antiseptics, of cyanide of mercury or silver, the double cyanides of gold and potassium, and the oxycyanide of mercury.

During Certain Industrial Operations liberating Compounds of Cyanogen

Compounds of cyanogen are formed during the following operations: the manufacture of ammonia gas; the preparation of compounds of cyanogen while heating organic waste materials with alkalis; the preparation of phosphoric acid from bones, and of oxalic acid by treating wood with nitric acid; during the distillation of cherry stones if done carelessly; during the burning of celluloid; the manufacture of artificial silk; and the manufacture of illuminating gas.

Hydrogen cyanate, apart from the manufacture of illuminating gas, may be met with in electro-plating, photography, and tanning. Finally, the use of some cyanide compounds as manure must be noted, the danger accompanying which was pointed out by Stritt as far back as 1909.

Toxic Action

Among the compounds of cyanogen particular attention should be paid to hydrocyanic acid, to its two principal salts, the cyanides of potassium and sodium, and to the ferri- and ferrocyanides.

The other compounds of cyanogen are of very little importance in industrial hygiene.

Their toxicity arises from the fact that these products prevent the absorption of oxygen from the blood by the tissues. That is why the venous blood keeps the clear red colour of arterial blood. The results are a cessation of organic gaseous exchanges with signs of asphyxia, a diminution in the alkalinity of the blood, and the sudden appearance of lactic acid.

The toxic effect on the central nervous system is shown by signs of paralysis characterised by a very definite effect on the vaso-motor centres (Koelsch).

The toxicity of cyanogen, which has also an irritant effect on the skin and mucous membranes, is about a quarter of that of hydrocyanic acid.

Cyanide of potassium exerts its poisonous action in the same way as hydrocyanic acid, but not so powerfully. Its toxicity is, moreover, in proportion to the quantity of hydrocyanic acid contained. The alkaline cyanides are as a matter of fact characterised by the ease with which they give off hydrocyanic acid, even in the presence of weak acids. The metallic cyanides only have their hydrocyanic acid displaced by strong mineral acids.

The fatal dose of cyanide of potassium is on an average 0.20 grm. for an adult. This product acts on the blood by forming cyanhaemoglobin, and in large doses, cyanhaematin.

Collins and Martland have been able to produce peripheral neuritis in animals with degeneration of the axis cylinders and of the anterior horns of the spinal cord.

Independently of their general toxic effect alkaline cyanides exert a decided caustic effect on the skin, due to direct irritation either by the liquids or by the fumes which are given off, or due to an indirect inflammation of the skin from re-absorption, or to an internal action due to inhaled hydrocyanic acid.

Ferri- and ferrocyanides are not poisonous in themselves, but in the presence of acids they may liberate hydrocyanic acid which constitutes the danger.

Cyanhalogens and cyanamides are very toxic and irritate the mucous membranes acutely. The nitriles and aliphatic nitriles and the chloride of cyanogen are exceedingly toxic.

The most important path of entry for the poison is by the respiratory tract. Absorption of the fluid compounds by the skin is very rare. Out of 26 cases
of acute poisoning, which were rapidly fatal, reported by Rüestrup in 1926, 3 were of occupational origin. An interesting point to be emphasised is that in two of these cases, as well as in that of Davanne, the cyanide of potassium only came in contact with the skin. It is possible that the absorption was facilitated by the very alkaline and very caustic action of the cyanide itself on the skin. Koelsch, however, insists upon this as a path of entry, especially when the integrity of the skin is impaired by small wounds, as by splinters from metals among electro-platers, and the macerating action of certain products. In the case of Soberheim and of Simon, the absorption of the poison was facilitated by a pre-existing wound of the skin.

It should be noted that some recent researches of Violle in 1927 have brought to light a specific anti-toxic effect exercised by glucose solutions.

**Statistics**

Although it is a question of highly poisonous products, and products which are used, or very commonly given off, in numerous industrial operations, the cases of poisoning which have been reported are quite rare.

The majority of cases of poisoning observed have been due to cyanide of potassium.

Some cases of poisoning by gilding by means of cyanide of potassium were reported in Germany in 1999 and in 1964. Niewerth in 1907 reported a fatal case at a potassium cyanide factory, in a workman who had inhaled hydrocyanic acid which came from a leaky exhaust pipe.

The German factory inspectors reported in 1920 the fatal case of a woman jeweler who had been previously washed with a solution of potassium cyanide. In 1921 a fatal case occurred in Prussia in the process of electro-plating by means of cyanide baths.

In England, in 1923, Bridge reported 7 cases of poisoning, one of which was fatal, which occurred among workmen employed in emptying casks containing potassium cyanide.

In Switzerland, from 1918 to 1925, 12 cases of poisoning by cyanogen and its compounds were reported; 1 in 1919; 2 in 1920; 3 in 1922; 4 in 1923; and 2 in 1925.

Some cases of chronic poisoning have been reported by Robert, 2 cases from the cyanides used in gilding, and by Martin, one case of a young girl of twenty-one years of age employed on polishing silver articles by means of a mixture of lime and a double cyanide of silver and potassium.

Particulars concerning dermatitis due to cyanides are also available. Thus, for instance, Chatet has noted ulcers of the fingers in electro-platers. The Bulletin of the New York State Labour Bureau reported, in 1912, 5 cases of dermatitis of the hands which occurred during electro-plating parts of typewriting machines. Out of 250 workers employed in electro-plating by copper, 7 cases of ulceration of the hand were reported. Knowles has reported a number of cases in different categories of metal workers—engravers, polishers and foundrymen; Koelsch has also reported numerous cases among electro-platers, especially when they indulged in the bad habit of taking articles out from the electro-plating baths with their bare hands. In 1921 several cases of eczema were noted among women employed as brushers in the industry of precious stones.

In Switzerland, from 1918 to 1925, 6 cases of dermatitis due to cyanogen and its compounds were reported (1918, 2; 1919, 1; 1920, 1; 1924, 1).

In the United States, Reed, of Kansas University, has reported 14 cases of chronic occupational poisoning by chloride of cyanogen products in a small business making this product. The cases occurred among workmen who had been exposed to the inhalation of the gas for eight months.

**Symptoms**

In the particularly acute form, following upon absorption of strong doses of poison, asphyxia is instantaneous, with dilatation of the pupils, loss of consciousness, panting, cyanosis of the skin and mucous membranes, collapse and death.

In the acute form of poisoning are noted vertigo, headaches, nausea, congestion of the head, oppression, palpitations, constriction of the throat with irritation and dryness of the pharynx, vomiting and dyspnoea. Consciousness is retained. In a later stage follow an fall of the pulse, shiverings with a sensation of cold, sweats, convulsions, involuntary micturition and loss of consciousness. In the asphyxia stage there is a temporary suspension of respiration, slow action of the heart, lividity of the skin and mucous membranes, and fall in temperature. Death occurs in a few hours, even though oxygen is inhaled.

In a case of subacute poisoning, reported by Martin and quoted by Hamilton, the following symptoms were observed: lassitude, cough, dyspnoea, pains in the head and kidney region; weakness, necessitating going to bed; breath smelling of bitter almonds; colour pale at first, then red; pulse very feeble, soft and rapid; accelerated irregular and laboured breathing; pain in the back and chest; uncontrollable vomiting; cramps of the diaphragm and abdominal muscles. Improvement in the condition only
showed itself at the end of fifteen or sixteen days. During the next seven months the victim showed signs of a profound anaemia with weakness, somnolence, headache, ataxic gait, impossibility of standing upright, and drooping eyelids.

Chronic poisoning is rare, and its existence is even denied by some authors (Hamilton). Füthner is one of those who, basing his opinion on experiments made on animals, considers that the condition created by repeated exposure to the poison is not genuine chronic poisoning, but a more decided susceptibility to very small doses of poison. Lehmann, however, has reported two cases of poisoning by cyanide of potassium used for silvering by hand.

However that may be, some authors have established the symptomatology of the chronic form as follows: headaches, vertigo, malaise, feeling of lassitude, and weakness; unsteady gait, which is dragging and hesitating; difficulty in moving the jaws in some cases; nausea, vomiting, loss of appetite, disorders of the gastric and intestinal functions; albuminuria; suppression of tendon reflexes; disorders and irritation of the throat and respiratory system; diminution in cardiac activity, with weak pulse, palpitations and faintings; and diminution in the sensitiveness of the skin.

Collins and Martland in 1908 reported a special case, viz. that of a workman of sixty-eight years of age, employed for two years in polishing the silver of an hotel, by plunging it in a solution of cyanide of potassium used for silvering by hand. It should be added that in workmen who handle potassium ferrocyanide a red coloration of the skin and hair is found (Merian).

In poisoning by chloride of cyanogen, C. I. Reed has collected the following symptoms:

In acute cases: dizziness, nausea, strong lachrymation; misty vision, difficult breathing, cough, tottering gait and prostration for several hours.

In chronic cases: muscular weakness, lassitude, pulmonary congestion, irritation of the skin, huskiness, conjunctivitis, oedema of the eyelids; irregularity of the pulse varying with the extent of the exposure to the poison; diminution of the appetite with abrupt crises of abnormal and unnatural hunger; loss of weight.

These symptoms resemble closely those of chronic poisoning by hydrocyanic acid, but the loss of weight, the pulmonary congestion and the cutaneous lesions lead to the supposition that chlorine also plays a part. Experiments made on animals seem to confirm this supposition. According to Winteritz, Wislocki and Finney, the acute symptoms produced by chloride of cyanogen are confined to pulmonary oedema and congestion with slight inflammation of the small bronchi. In less serious cases there is bronchial catarrh with a slight localised enphysema, and but rarely patches of broncho-pneumonia.

Diagnosis is easily made from the symptoms presented and knowledge of the operations carried on.

Prognosis is fatal in acute and very acute poisoning, favourable in the others.

DETECTION

Cyanogen in the Air

(a) A piece of paper impregnated with 1 per cent. sulphate of copper is hung in the air, after it has been soaked in a 1 per cent. alcoholic tincture of guiacum resin. In the presence of cyanogen an intense blue coloration is quickly produced.
(b) Guignard’s test. A piece of paper, prepared by immersion in 1 per cent. sodium carbonate and then dried, is dipped in an aqueous solution of 1 per cent. picric acid solution. When hung in the air it turns a more or less deep red colour due to isopurpurate of soda, alter a period varying in length with the quantity of the toxic products present.

c. Reaction with cobalt nitrate. Absorption by steam and then treatment with cobalt nitrate. In the presence of hydrocyanic acid a blue coloration is produced; in the presence of cyanogen there is no coloration.

Detection of Cyanides

Treat a small quantity of the product submitted for analysis with a solution of ferrous sulphate mixed with ferric phosphate; then saturate with potash; heat slightly and acidity with hydrochloric acid. In the presence of cyanides, a coloration occurs and then a precipitate of Prussian blue.

**Hygiene**

The flooring should be impermeable in order to ensure effective disposal of waste water. Workplaces should be constructed of non-inflammable materials. Machines and apparatus which should be scientifically planned should not leak in any way and should be enclosed or placed under cowls with efficient exhaust. Gases and fumes produced in furnaces and retorts should be burnt. The boilers should have covers and cowls, directing gases and steam into a chimney. Vigorous ventilation must be provided in work-places. Measures must be adopted against disagreeable and injurious emanations, e.g. compounds of sulphur and ammonia, and against the black dust. If Prussian blue is produced by direct calcination of animal matter by potash, it is necessary to apply all the measures laid down for the manufacture of animal charcoal. The accumulation of offensive smelling residues must be prevented; and waste from manufacture must be cleared away daily. Refuse must be carefully collected and treated; water used for lixiviation must be purified completely. Gases which escape during condensation should be subjected to pyrogenetic purification.

A greater tolerance is allowable in the case of the manufacture of blue from materials which have already been calcined, and from gas residues.

In the manufacture of ferri- and ferro-cyanides by the chlorine process, the liberation of the chlorine should be done under hoods with powerful exhaust; the excess of chlorine should be neutralised; the operations must be carried out in closed receptacles and all measures should be taken to prevent the escape of the gas. In the chlorinating shops apparatus should be always available for neutralisation (ammonia).

Speaking generally, the installation should be as far as possible mechanical and automatic, and such as to ensure absolute cleanliness of the workplace and the equipment.

If animal matter is used in the factory special measures should be laid down; the premises should be at a distance from dwellings; the materials should be disinfected on their arrival at the works and sent on to calcination with as little delay as possible. Mixing should be done on an impermeable floor in the open air, or under very dry sheds.

Condensation water can be used for making ammonium sulphate. Waste water must be discharged into a sewer, or turned into a river if it has been purified.

When adequate measures are taken the danger is not great. As a matter of fact, Leymann reported that in a large German factory which used daily several tons of sodium cyanide, there had not been a single case of poisoning.

In the use of cyanides great precautions have to be taken. In Thuringia a business which carries on soaking by means of cyanide of potassium installed in 1922 a system of exhaust ventilation, associated with an electric alarm, which rings automatically as soon as the fumes are given off.

From the point of view of individual hygiene, the most thorough cleanliness must be insisted on: baths, lavatories, scrupulous cleaning of the hands with soap, and the application of ointment of zinc pastes and lanoline cream against the dermatitis caused by cyanide. Working clothes and head covers should be used. India-rubber gloves and respirators should be worn. Pin-cers or other special apparatus should be used for taking out objects from the electro-plating baths. Eating in the workshops should be prohibited.

Medical supervision should control the choice of the personnel and especially the elimination from electro-plating operations of workers with sensitive skins, or those affected with diseases of the skin or wounds of the hands.

Instructions should be given to the workers on the poisonous nature of the products which are made or handled, or may be given off during the various industrial operations.
LEGISLATION

Women are excluded from the manufacture of cyanides, Prussian blue and other compounds of cyanogen in Argentina, France, the Netherlands and Switzerland; young persons under sixteen years in Belgium; boys under fifteen in Italy and Japan; under sixteen in Greece and Spain; under eighteen in the Netherlands and Switzerland; women under eighteen years in Greece; under twenty-one in Italy, Japan and Spain.

There is no special legislation dealing with the manufacture of cyanogen compounds, for which the general rules laid down for the chemical industry are sufficient. The provisions made in the British Regulations of 11 July 1922, relating to the manufacture of chemical products cover also the manufacture and recovery of compounds of cyanogen (manufacture and recuperation).

Compulsory notification of cases of poisoning from cyanogen and its compounds is provided for in the Netherlands, and in the States of Victoria and Western Australia, and from eruptions due to cyanides in the mandated territory of South West Africa.

Compensation for occupational diseases due to cyanogen and its compounds is provided in the following countries: Finland, Japan, Queensland, Switzerland, South Africa (dermatitis due to cyanides), Western Australia, and in the countries which compensate for occupational diseases by defining them, and include in the list diseases of the skin caused by liquids and poisons.

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Diamond Cutting


PROPERTIES

The diamond is an elementary substance (from the Greek "adamas" — indomitable) formed of crystallised carbon. The crystal form belongs to the regular group. The principal form is the regular octahedron, the faces and groins being always slightly bowed. The groins and angles are the hardest part. The growth or formation takes place from the centre in the direction of the three principal axes.

The raw diamond has a lead glance; specific gravity 3.5. It stands at the head of the Mohs scale in respect of hardness. A diamond can only be cut by a diamond. Other properties: a low conductor of heat and electricity; strong power of refracting light; very difficult of combustion; a fairly high penetrability by X-rays; great transparency.

It is found in alluvium and in white quartzite (itacolumite). The broken pieces of quartzite are ground in crushing mills and the diamonds are picked out in flowing water. Diamonds are found in British India, the Dutch Indies, the Ural Mountains, Brazil, California, Australia and South Africa.

USE

Diamond cutting is carried on in Amsterdam, Antwerp, Gex (France), Hanau, London, and New York. The object of the cutting is the obtaining of certain forms, the classic form being the brilliant and the simpler the rose diamond.

The processes are splitting, sawing, rounding and polishing. There is also the process of setting as ancillary to sawing and polishing. Splitting or sawing converts impure material into pure stones without flaws or blemishes.

Splitting. — For the purpose of splitting, the stone is fixed on a palm-wood stick by means of a so-called cement composed of shellac, resin, sand or powdered glass. This cement is heated over a gas or spirit flame until it can be kneaded. The stone is pressed into it in the required manner and in the desired position. It is cooled in a bowl of water or in the mouth of the workman, a proceeding which has a characteristic effect in wearing out the incisor teeth. A piece of diamond with a sharp edge is fixed in the same way on another stick, and with this the splitter makes an indenture in the stone at the exact spot desired. He then fixes the stick holding the stone which is to be split in an opening in a block of lead screwed on to the work-table. He places a blunt knife in the indenture, gives the knife a short, sharp blow with a wooden club, which splits the stone by wedging. The pieces of diamond thus split off partly remain on the leaden block and are collected by the splitter with moistened thumb and forefinger which leads to contact with the lead (which is, however, of little importance). Two forms result from the splitting: the tops, which are cut into brilliants, and the flatter ends, which are cut into rose diamonds.

Sawing. — Sawing is essentially a grinding process, the grinding of the stone into two pieces by means of a thin, rapidly rotating disc of phosphor bronze prepared with "bort" a mixture of diamond powder and olive oil. The diamond is fixed in a pair of pincers by means of steel pegs or plaster or solder. Work at the sawing machine is carried out by men and women in a standing posture. The solder consists of two parts lead and one part tin. Very little dust is produced in sawing.

Rounding. — This is not a cutting process, although called snijden (cutting) in Dutch. The object of rounding is to make the stone clear for the polisher, i.e. a first fashioning of the
stone by the breaking off of sharp edges and salient points. This is carried out in two ways:

1. **Hand-rounding:** two diamonds, fixed with cement on sticks of wood, are rubbed together with considerable energy. The rounder sits in a stooping position; the strong pressure produces, in course of time, hypertrophy and flattening of the ends of the thumbs, a lateral deviation of the end of the right forefinger, the formation of callosities on various parts of the fingers, and even atrophy.

   The method of hand-rounding is used for very small stones and for rose diamonds.

   A mixture of diamond powder and olive-oil, necessary for polishing diamonds. The stone, fixed in a dop, is held against the disc under pressure.

   Two kinds of dops are in use:

   **The solder dop:** more or less hemispherical in form and having a flexible handle of red copper attached underneath by means of a thread screw. In this dop is placed a very plastic solder consisting of two parts of lead to one part of tin. It is remelted from time to time.

   An expert worker (setter) fills the dop till the solder rises conically above the surface and into this he sticks the diamond, leaving exposed the facet to be polished ("setting in lead"). For this purpose he heats the dop slightly on a bunsen burner until it is rendered malleable. The worker then presses the solder between his naked forefinger and thumb to make the stone fast, and having cooled the dop in water he fixes it by the handle in the polishing tongs, which are provided with feet. The diamond in the dop is placed on the disc and the tongs are sufficiently weighted to press the stone with the necessary force against the revolving disc. The weights are flat pieces of iron or iron loaded with lead. When one facet is polished, the setter sets the stone again in the manner above described. The setter

2. **Machine-rounding** is carried out on a lathe with an adjustable axis, driven by electric power.

   A stone is fixed with cement on the revolving axis of the machine, another on a long, fairly heavy stick; the manipulation is the same as on any turning lathe. The work is less hard than hand-rounding. It is performed in a sitting posture.

**Polishing.** — The polisher sits at a bench, on which is placed the so-called mill, which is in effect a porous cast-iron disc, rapidly revolving horizontally. The disc is provided on its upper side with a mass of shallow radiating indentations, containing a mixture of diamond powder and olive-oil, necessary for polishing diamonds. The stone, fixed in a dop, is held against the disc under pressure.

   Two kinds of dops are in use:

   **The solder dop:** more or less hemispherical in form and having a flexible handle of red copper attached underneath by means of a thread screw. In this dop is placed a very plastic solder consisting of two parts of lead to one part of tin. It is remelted from time to time.

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![Fig. 48 — A Dutch diamond cutting factory (natural lighting: "shed" system).](image-url)
prepares the dops for four polishers at once, and is continuously in contact with lead.

During the polishing process, the polisher from time to time removes the dop from the disc for the purpose of examining the facet of the stone. In order to do this, the dop is rapidly rubbed on different parts of the hand (the ball of the little finger and the back of the hand) and jacket, with much soiling from solder in consequence. The working jacket is in many cases only washed once in several weeks. The polishing of diamonds, especially those of the size of a pin's head, involves heavy eye strain.

The mechanical dop: this is only used for larger diamonds. Lead is not used with this apparatus. It consists of a steel rod with a socket, in which the diamond is placed and pressed from above by the two jaws of adjustable tongs fixed on the rod. The mechanical dop makes the setter superfluous. Diamond polishing produces little dust.

The cleaning of the diamond is carried out by parboiling with nitric acid in a glass vessel with an asbestos-glass stopper. There is danger from nitrous fumes in case of breakage.

For tracing diamonds falling on the floor, the dust is swept and the stones separated by burning. This produces a disagreeable smell.

A supplementary process to diamond cutting is the scouring of the discs. The surface of the disc, when it becomes uneven with use, is rubbed smooth with carborundum and emery. The workman holds the disc firmly with one hand, turns it repeatedly and scours with the other, holding the stone firmly and applying great pressure. The work is done standing. It is laborious work and a considerable amount of stone and metallic dust is raised. It sets up, moreover, calllosities on the right hand.

The product of cutting is the brilliant and the rose diamond.

Dangers

The sitting posture, bending forward, may predispose to respiratory troubles, and, in time, to digestive disturbance and upset the general state of nutrition. Danger from dust is minimal. Risk of chronic lead poisoning is small for the splitter, but greater for the setter and polisher. (See article "Lead Poisoning").

The danger of chronic CO poisoning for the setter is increased by the use of coal gas (see article "Carbon Monoxide"). The risk of acute intoxication by nitrous fumes (see this article) must not be overlooked, and the same applies in the case of the ocular and

Fig. 49. — Heating the "dop" by electricity.
bronchopulmonary trouble referred to above. As regards these, as early as 1892, Lloyd Owen, an ophthalmic surgeon of Birmingham (a centre for the precious stones industry), called attention to the frequency of visual defects among diamond workers, and as a result of his long experience his opinion was that they were due to inaptitude for the specific work rather than to the injurious action of this upon the sight of the workers. Without giving details based on the evidence of old writers (Layet 1871, Hirt and others) who used data as to the health of diamond workers in Amsterdam, Hanau, Antwerp, Oldenburg, etc. — data of doubtful value to-day — one must admit that even amongst them there were differences of opinion to be explained by different hygienic and economic conditions in the different factories. However this may be, the conditions required by the work — attention, skill, smallness of the object, intense light concentrated often through a bowl of water, etc. — sufficiently explain any eye affections.

**STATISTICS**

**Belgium.** — In 1911 Buyse (Medical Inspector of Factories) found minor signs of plumbism in the polishing shops of Antwerp. They were fine, new premises; hours were short and the staff limited to young apprentices. The classical signs, however (blue line, colic and constipation), were remarkable and the absorption had definite relation to the manipulation of the lead used for, and in, the dop, and in sorting the diamonds in the lead contaminated mass.

A later enquiry on 712 workmen in Antwerp has brought to light a good deal as to lead poisoning among 375 diamond cutters. Of the 712 workmen belonging to 3 shops, 591 (63 per cent.) were in good, and 121 (16.99 per cent.) in indifferent health. Of the 375 persons examined, 50 (14.93 per cent.) showed a blue line, 134 (33.73 per cent.) had less than 60 per cent. haemoglobin, and only 3 (0.80 per cent.) showed punctate basophilia. (These three cases belonged to the same factory employing 265 workmen, so that the percentage works out at 1.13.)

**Germany.** — Koelsch in 1914 found signs of lead absorption in 16 out of 50 polishers examined, in 6 a slight blue line, and in 1 colic. Duration of employment had been in 32 of the 50 cases from 1 to 6 years, in 8 cases from 7 to 10, and in 10 from 11 to 25.

**Netherlands.** — Very few cases of lead poisoning have been reported of late years.

**HYGIENE**

In addition to general factory hygiene (cleanliness, good ventilation and adequate lighting, sufficient and suitable washing accommodation and cloakrooms), measures appropriate to an unhealthy trade should be applied to the industry. Each sorter using a solder dop and each polisher should have a special linen overall or jacket to be changed every week, and the introduction of food and drink, or eating and smoking during work, should be prohibited.

Further, hours of work should not exceed eight, and an interval of two hours should be allowed for meals at home and for careful washing.

Medical examination on first employment, and periodically later, should be required. The mechanical dop should be adopted for stones of the larger size.

Leaden weights should be replaced by iron, and tongs should be automatic.

It would be interesting to ascertain if it were possible to find something to take the place of lead in the alloy and of the leaden slab (see the article "Jewellery Industry").

The boiling of the diamonds in nitric acid should be done under a ventilating hood. The solder should be melted outside the workroom.

**LEGISLATION**

**Netherlands:** Regulations as to Work (Arbeidsbesluit), 1920, Art. 27 and 33, cat. F. — Regulations on Safety (Veiligheidsbesluit), 1916, Art. 1, cat. C.; Art. 1, cat. F.; Art. 11c.

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Dimethylsulphate


This is a dimethylene ether of sulphuric acid with the formula \( \text{CH}_2\text{O}_2\text{SO}_3\). It is a colourless or yellowish liquid of oily consistency with a slight special smell and piquant taste, like mint. Its specific gravity is 1.25 and boiling point 185.5° C. Its off greyish vapour as soon as the temperature reaches 50° C. It is only slightly soluble in water. Heated in the presence of water or a solution of caustic soda, dimethylsulphate decomposes readily into methyl alcohol and sulphuric acid.

INDUSTRIAL PROCESSES

It is prepared from pure methylylsulphuric acid (containing no water, hydrochloric acid, or other impurities). A calculated quantity of sulphuric anhydride in methylalcohol is distilled under a vacuum at 0° C. or preferably at —5° C. It is prepared also in a distillation, under a vacuum, a mixture of chlorosulphonic acid and methyl alcohol is distilled under a vacuum at 0° C. or preferably at —5° C. This operation gives rise to a strong development of heat, which is avoided by using as the solvent carbon tetrachloride. The tetrachloride is recovered by distillation and is used over and over again.

Dimethylsulphate is further obtained by treating oleum (at 5 per cent. sulphuric anhydride) by methyl oxide (\( \text{CH}_2\text{O}_2\)), the latter being obtained by catalytic dehydration of methylalcohol in presence of \( \text{H}_2\text{SO}_4\).

SOURCES OF DANGER

1. In the course of manufacture, the dangerous processes are especially those conducted at boilers from which toxic vapours escape.

2. In the course of its industrial use, as a methylating and alcoholising agent in the preparation of organic chemical products, colouring agents, dimethyl-aniline, methylated ethers and amines, artificial scents, etc. It has also been used as a substitute for chlorides and iodide of methyl. During the war it was used as an asphyxiating or toxic gas by mixing it with other substances, such as chlorosulphonate of methyl (an intermediate product of the methylation of chlorosulphonic acid), chlorosulphonic acid, etc.

Account has also to be taken of the toxic action which can arise in the course of these operation from the substances used or given off (arseniuretted hydrogen, nitrous fumes, etc.).

TOXIC ACTION

Dimethylsulphate is, with phosgene, one of the most dangerous substances in the colour industry, the more so as no specific antidote is known. It exercises a double action:

(a) Local, intense caustic action (already illustrated in 1902 by Weber) on the skin and irritant action on the mucous membranes (from the vapour). The caustic action takes place immediately after contact with the liquid product. It varies from simple redness of the affected part to the production of phlyctenular ulcers and necrotic patches according to the duration of contact. The mucous membranes take longer to react to the vapours — only after some hours.

(b) The general action is sufficiently rapid after absorption of the toxin. It shows itself in effects on the central nervous system (convulsions, coma, paralysis, etc.), on the cardio-vascular renal circulation, on the blood, and on nutrition. Auer (1901) noted in animals remarkable effects of marked analgesia after some hours exposure to the poison, reaching its highest point (anaesthesia) at the end of twenty-four hours. If the animal survived the analgesia was apparent even six months later.

An increase in the number of red blood cells as well as leucocytes has been described without change in the differential count (Preti). Nutritional disturbance shows itself in increase of the urea and uric acid eliminated. The peripheral temperature may reach 40° C. and falls by lysis.

The poison is absorbed as a vapour and the channels of absorption are the respiratory tract, inhalation and, to some extent, the digestive tract (ingestion).
The pathogenesis is rather obscure; some authors consider that the effects are due to the whole molecule of dimethylsulphate, and not to the products when it splits up into sulphuric acid and methyl alcohol. Others, on the other hand, think that, once it has entered the system dimethylsulphate undergoes, by hydrolysis, a slow saponification due to the alkalis and secretions of the tissues, with formation of sulphuric acid in a nascent state which exercises on the protoplasm (skin and mucous membranes) a toxic action very much stronger than ordinary sulphuric acid.

In experiments on rabbits, Bentz and Cameron found the blood black and fluid and showing in the spectrum the lines of methaemoglobin, with intense congestion of the liver and kidneys and degeneration and oedema of the lungs.

According to Weber, diethylsulphate when it produces the same lesions as dimethylsulphate, only the caustic action is less severe.

STATISTICS

Such statistics as there are are few in number.

Leymann, in 1901, described 2 fatal cases—one in a chemist as a result of caustic action on a part of the body and from inhalation of the vapour; the other in a workman from inhalation of vapour. Post-mortem intense caustic action of the respiratory tract was found. In 1902, Weber described 3 severe cases, of which 2 were fatal, in men working in a dyeworks. Klocke (of Bochum) reported several cases. In 1906, Erdmann one in 1909. One fatal case of pneumonia was described in a Swiss chemist in 1912 (Egli-Rüest). Two acute cases were treated at the Industrial Clinic, Milan (Preti). They occurred in a cellulose factory. In 1920 Mohlau described 2 cases in the United States; Legge in 1925 mentions 2 cases of conjunctivitis in Great Britain.

PATHOLOGY

While liquid dimethylsulphate sets up immediate symptoms of irritation on the skin, the vapour does not act in the same way on the natural channels and only after the lapse of some time is damage caused.

The lesions induced by splashes of dimethylsulphate on the skin vary with the duration of contact and quantity of the liquid. A few drops set up the same kind of burns as does sulphuric acid, but they take a long time to heal. In severe cases phlyctenular ulcers occur or necrotic patches on the skin. The lips are swollen, very red and covered with very painful aphthous plaques, making feeding a difficult matter. The nasal mucous membrane is also swollen and produces a secretion so abundant as to hinder nose breathing.

The eyes are affected painfully (burns), there is severe blepharitis showing itself in a punctiform erosion and cramp of the eyelid; lachrymation and photophobia, sometimes so intense as to necessitate giving up work. Swelling and oedema of the eyelids, hyperaemia of the conjunctiva, have also been observed, changing rapidly in six to seven hours after exposure to the vapour of dimethylsulphate into kerato-conjunctivitis. The main substance of the cornea becomes sometimes oedematous and the height of the inflammation, reached generally in twenty-four hours, diminishes gradually in intensity. After regeneration of the dead endothelium, extremely fine spots on the cornea remain, situated in the middle and superficial layers of the parenchyma. Experimental reproducing experimentally the ocular lesions due to the vapour of dimethylsulphate, has set up a parenchymatous keratitis from oedema of the corneal parenchyma and degeneration of the endothelial cells. In Mohlau's 2 cases, six weeks after the intoxication photophobia remained and one of them had total colour blindness and visual acuity reduced to one-tenth.

In the pharynx a white colour of the walls and uvula and inflammation of the throat are described. Caustic action on the mucous membrane of the pharyngeal walls and upper air passages can effect their complete destruction. The respiratory symptoms show themselves in intense thoracic pain, hoarseness, cough sometimes dry and sometimes accompanied by abundant serous and greenish expectoration, dyspnoea, occasionally acute bronchitis, and in certain severe cases by pneumonia, often double and almost always fatal (Lewin).

The constitutional symptoms are marked: high fever, small irregular pulse, fall in arterial pressure, slowing of the respiration, signs of nephritis (albuminuria with granular casts); jaundice (noted once only). In one case examination of the urine brought out notable increase in the quantity of phosphates and sulphates excreted.

Involvement of the central nervous system is shown in severe cases by somnolence, convulsions, delirium, coma, ending generally in paralysis and death in some hours.

Chronic intoxication has been described once only with symptoms of violent catarrh of the respiratory tract, obstinate catarrh of the eyes keeping its victims away from work for three months (Leymann).
Diagnosis can only be made with certainty if the possibility of the poisoning is known.

Prognosis should be withheld, especially as in serious cases the course is nearly always to a fatal issue.

Hygiene

First aid.—The parts of the body and the clothing impregnated with dimethylsulphate should be neutralised by ammonia. A solution of bicarbonate of soda should be always at hand for distribution to workpeople when the vapour is inhaled.

General measures of hygiene are the subject of a leaflet issued for distribution to workpeople by the Factory Inspectorate of Baden. They include the following:

All industrial processes should be carried on in closed apparatus. When the substance has been manufactured it should be despatched along closed and airtight pipes to receptacles. Removal of the product from these receptacles should only be done under exhaust ventilation. There should be no junctions in the piping. If this is not possible, they should be rendered absolutely airtight. All escapes of gas or vapour into the workrooms are to be avoided. The gases should pass into a chimney opening 3 or 4 metres above the roofs.

When the apparatus is opened in order to remove the residues from the manufacturing processes or for cleaning purposes, a jet of pure water should first be directed on them to keep down escape of dust. Water jets should be fixed outside the workrooms to sprinkle water quickly and carry away every substance which might be present.

Workmen should be provided with breathing apparatus, the sponges of which should be dipped in an aqueous solution of soda or potash.

Work should only be carried on by qualified workmen under the supervision of skilled foremen.

Workpeople should also be kept informed by leaflets and posters of the risk run.

An initial medical examination should allow of the elimination of workmen suffering from acute or chronic affections of the eyes and respiratory tract or who are predisposed to such.

Legislation

Compensation for lesions set up by dimethylsulphate is provided for in Switzerland.

Dinitrobenzene


Properties

Three isomers of dinitrobenzene are known. The first is C₆H₄(NO₂)₂, of which only the meta-dinitrobenzene: NO₂

\[ \text{NO}_2 \rightarrow \text{NO}_2 \]

discovered in 1841 by H. Deville, is used commercially. It is a stable substance, solid at ordinary temperature, which, in the pure state, forms inodorous and colourless flakes, but is generally slightly yellow. It melts at 89.7° C., boils at 302.8° (at 770 mm. of Hg), is almost insoluble in water, but, on the other hand, is soluble in lipoids: 100 parts of benzene dissolve, at 18° C., 39.5 parts of meta-dinitrobenzene, and 100 parts of alcohol at 20° C. dissolve 3.5 parts.

The other two isomers are also solid and are distinguishable from the meta compound chiefly by their melting points: 116.5° C. for the ortho-dinitrobenzene and 172° for the para-. They are a little more soluble in water than m.-dinitrobenzene. The two are formed in small quantity during the preparation of the meta compound, but they have no technical use.

The homologue 2,4-dinitrotoluene resembles dinitrobenzene in all its essential properties: it melts at 71°, dissolves under the same conditions as m.-dinitrobenzene.

Preparation

M.-dinitrobenzene is obtained by a second nitration of mono-nitrobenzene. This nitration, which is carried out on crude nitrobenzene obtained from the

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LEYMANN, in Concordia, 1901, p. 30.

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first nitration, may immediately follow the first nitration without preliminary purification of the crude nitrobenzols. After running off the residuary acid, an acid mixture is slowly introduced afresh into the vats. This acid mixture consists of 135 parts of concentrated sulphuric acid and 45 parts of nitric acid at 46.8° B. for 60 parts of the crude nitrobenzols. The nitration is carried on first at a temperature of 70° C. which is later raised to 115° C. (for description of the apparatus, see article "Nitration of benzene"). When the nitration has terminated, in about eight hours, after separation of the mixture which is cooled to 90°-100° C., the acid is drawn off and used again, in the same way that residuary acid from nitrobenzene is used (see that article).

The dinitrobenzene, still in a melted state, is next injected by pressure into closed washing tanks where it is freed, with the aid of hot water, from any traces of acid by bubbling through with steam. It is then decanted several times at the temperature of 90° C. When plunged into cold water dinitrobenzene solidifies and appears in granulated form as a fine crystalline powder; then it is freed from water and any trace of oil which it may contain, in large tanks, either by centrifugation or by aspiration. At this stage several washings through filters with tepid or cold water may be effected.

The powdered dinitrobenzene which remains in the desiccators or on the filters is finally separated from moisture by heating to 90°-100° C.; it is then poured either into flat pans, or straight into receptacles for transport, and left to solidify. Purifying by crystallisation from hot benzene is only carried out rarely.

During the process of nitration, m.-dinitrobenzene is chiefly obtained; but the two isomers also occur in small quantities, up to 7 to 10 per cent., the proportion between the ortho compound and the para varying according to the acid mixture used. They are generally eliminated during the process of washing the dinitrobenzene.

Dinitrotoluene is prepared in the same way starting from p.-nitrotoluene, and dinitrochlorbenzene starting from p.-chloronitrobenzene, nitration being carried further at a higher temperature by the use of a more concentrated acid. The last-named product can also be obtained by chlorination of m.-dinitrobenzene.

Uses
M.-dinitrobenzene, dinitrotoluene and dinitrochlorobenzene are used on a large scale in the manufacture of explosives. Dinitrobenzene and dinitrochlorobenzene mixed with other nitrated compounds are used in the preparation of explosives with nitrate of ammonium, e.g. roburite; dinitrotoluene is a constituent of cheddite, an explosive with a base of chlorates. It is also an intermediary product in the manufacture of trinitrotoluene (see that article), by nitration in three phases, extensively used in the explosive industry.

But these products are prepared and used on a still larger scale in the manufacture of coal tar dyes, wherein they are used chiefly in the manufacture of the corresponding dianimes by reduction with hydrochloric acid and iron filings. Dinitrochlorobenzene can also be partly transformed into the corresponding dinitrophenols by heating with a lye.

In the explosives industry the various compounds are crushed, and mixed in a warm atmosphere — in drying rooms with corridors — generally after being moistened with water; then the dried product is sifted. In the manufacture of explosives with a chlorate basis, the nitrated compounds are first of all dissolved in hot castor oil, and are subsequently manipulated in this form. In making munitions dinitrobenzene, or a certain quantity of this product, mixed with other nitrated aromatic compounds and with ammonium nitrate, is melted in closed receptacles, and then, while in the melted state, directed by pressure to the receptacles of the filling apparatus and thence, being kept all the time in the melted state, run straight into grenades or shells (see article "Trinitrotoluene").

In the coal tar dye industry, m.-dinitrobenzene is chiefly used for the preparation of m.-phenylenediamine and, on a smaller scale, of m.-nitraniline. The preparation of m.-phenylenediamine by reduction of dinitrobenzols by means of hydrochloric acid and iron filings is carried on to some extent in the dye industry, in which the acid solution filtered from the base is used for the preparation of mono and diazo dyes, such as chrysoidine, vesuvine, and Bismarck brown, by denitrating m.-phenylenediamine, which is not isolated at the start. These dyes form as the direct result of the transformation of the hydrochloric acid solution by a solution of nitrite of soda during the reduction of dinitrobenzene.

In addition, large quantities of m.-phenylenediamine are prepared and distributed commercially in the form of the base or chlorhydrate, intended for the preparation of numerous nitric colours.
The reduction is carried out in reducing apparatus similar to that which is used for the manufacture of aniline (see that article). It takes place at boiling temperature with the help of steam, and, as an intermediary product, yields m-nitroaniline. When the reduction is finished the iron is eliminated by means of soda and separated in filter presses. When the transformation into colouring material is not carried out at once, the base is crystallised by evaporating the solution, as well as the chlorhydrate, after the addition of concentrated hydrochloric acid.

In the same way m-toluyldiamine is obtained, starting from 2,4-dinitrotoluene by reducing with iron and acetic acid. M-toluyldiamine is also used in the manufacture of nitro colouring materials, just as dinitrochlorobenzene is used for the preparation of sulphur colouring materials.

**Sources of Dangers**

**During Preparation**

According to the results of numerous experiments, the manufacture of m-dinitrobenzene belongs to the most dangerous of operations in the preparation of nitrated hydrocarbons of the aromatic series and of other intermediary products of the dye industry. The danger of poisoning is due without doubt to absorption by the skin caused either by direct contact or by soiling the clothes, and also to an equally important degree to the inhalation of fumes. The inhalation of dust is of less importance, for during the manufacturing processes fine and dry particles capable of generating dust are scarcely ever formed. The workman runs a risk from contamination when removing the granulated product from the filters or desiccaters, and when carrying it to and charging up the melting apparatus, since these operations are done by hand. Discharging the melting apparatus and the crystallising tanks may also easily be a cause of contamination, either direct or when the product is upset on the floor.

The opinion of Zieger, based chiefly on experimental researches, is that danger from inhalation of fumes plays only a secondary part; but this opinion is contradicted by practical results. As a matter of fact, in addition to risk from generating fumes when discharging the product in the melted state, the fact that it is easily carried by steam constitutes a still greater source of danger, especially when washing the raw material. In the same way manipulation of residuary acids may occasionally be a cause of poisoning in which the same factor plays the chief role.

**During Use**

The use of dinitrobenzene and its homologues in the chemical industry, in view of their immediate change into the corresponding bases, only rarely constitutes a danger to the health of workers. The danger is greatest during manipulation in the explosives industry. During the war, dinitrobenzene, used as such, or constituting an impurity in such other explosives as trinitrobenzene, gave rise to numerous cases of poisoning during the filling of grenades. These poisonings were caused either by contact with the skin, or by inhaling fumes while filling munitions with the melted product. In Germany, after the war, the work of emptying grenades filled with dinitrobenzene was regarded as one of the most dangerous kinds of work carried out by firms who emptied munitions. Melting the product which filled the shell, by means of a jet of steam under pressure (Ausdüsen), was notorious for originating numerous cases of poisoning in which dinitrobenzene, readily carried by the steam, was the evident cause.

A fact which has come to light, as much in factories where dinitrobenzene is manufactured as in those where it is used, is that the danger of poisoning increases so extraordinarily during the hot season that this danger can only be met by suspending work during the summer months.

**Toxic Effect**

m-dinitrobenzene is easily absorbed, in quantities sufficient to take effect, through the digestive organs, but particularly through the undamaged skin. This absorption by the skin has been definitely demonstrated by experiments on animals.

Dinitrobenzene undergoes in the body a change into m-nitroaniline and is eliminated in this form by the urine, as Lipschitz has shown by recent work. One of the nitrates groups then undergoes a reduction into an amino group, a reduction which results in an intermediary product, nitrophenylhydroxylamine NO.\(-\text{(C}_1\text{H}_3)\)-NH\(\cdot\)OH. It is to this intermediary hydroxylamine group that, as is probably the case in the living organism, the action on the haemoglobin, with formation of methaemoglobin, is ascribed in the case of all the nitro and aromatic amino compounds of this category.
There is no hydroxylation of the nucleus — hydroxylation which with nitrobenzene and aniline leads to the formation of paraminophenol, a body capable of coupling up, in which form it is not poisonous and is easily eliminated by the urine. Owing to this fact, the process of recovery from the poison, and of its elimination, is much slower than that of poisoning — due to reduction of one of the nitrated groups. Doubtless this accounts for the greater intensity and the longer duration of the poisonous action.

The toxic action of m.-dinitrobenzene in principle resembles that of manitrobenzene (see article "Nitrobenzene"), but is much stronger and more violent. Its effect on haemoglobin and, among nervous symptoms, its paralysing effect are most important. But the action is cumulative, and for this reason the effects are slow.

(1) The action of m.-dinitrobenzene on the blood is shown by changes in the haemoglobin and the red cells. These latter are less resistant to haemolysis and, in consequence, are not so easily laked as in the normal (Röhl). Morphological changes also appear in the red cells: prickle forms, aniso- and poikilocytes, fissures and other signs of the destruction of the cells and of degeneration, e.g. the corpuscles of Heinz. The destruction of the blood cells rapidly leads first to a considerable diminution in their number which, according to experiments on animals, may fall to a million and less in a few days, and then to symptoms of regeneration. Leucocytosis and regeneration types of red cells, with polychromasia, megalocytes, megaloblasts, and sometimes also basophilic granulations, follow closely the forms of degeneration. As a consequence of the rapid destruction of red cells a deep chromojaundice appears. If the poisoning is prolonged, it leads on to secondary anaemia, when signs of degeneration of the red cells pass into the background.

In five cases of poisoning by DNB examined by Legge the number of red cells varied from 2,400,000 to 3,364,000; the number of leucocytes from 7,000 to 8,000 and the haemoglobin value from 10.2 to 13.4 (index: 1.1 to 1.7). On spectroscopic examination the methaemoglobin band was not found. None or very few of the red cells had basophilic granules. The leucocyte formula, given 66-79 per cent. poly- nuclears, 17-31 per cent. lymphocytes, 1-2 per cent. large mononuclears, 1 per cent. of transition forms, and 1 per cent. of eosinophiles.

For a long time opinion has not been unanimous with regard to the changes in the haemoglobin, changes which are indicated by marked cyanosis and dark-coloured blood, which is brown inclining to black. Although such earlier experts as Huber and Haldane were unable to prove the formation of methaemoglobin, even though Huber found a band in the red corresponding to the nitrobenzene band of Filehne, more recent experiments by Lipschitz and results obtained during the war have brought out that this substance is formed. With dinitrobenzene methaemoglobin originates in vitro in the presence of small portions of organs still alive, and is, as far as can be seen, intimately connected with cellular respiration, while the reduction of the nitrate group, provided the reaction is carried out simultaneously with the processes of cellular oxidation (Lipschitz). In serious poisonings, there is also detected in the blood serum, haematin, which is a more advanced product of disintegration of haemoglobin.

(2) Action on the nervous system.—The profound changes in the composition of the blood, particularly methaemoglobininaemia in serious acute poisoning, cause, by internal asphyxia, secondary symptoms of irritation and of paralysis in the central nervous system, with dyspnoea cramps and then asphyxia. For this reason Haldane and other experts explain, by anoxaemia, all the complex symptoms in poisoning by dinitrobenzene which include lesions of the central nervous system and death. It is, however, certain that there exists in addition a direct action on the nerves, which is of real importance, just as in the case of the other nitro and amino derivatives. However, the paralysing effects produced by dinitrobenzene are more violent than by the other derivatives. These effects attack the brain, the vasomotor and respiratory centres; and there result early vasomotor weakness, disorders of the mind with dilatation of the pupils — but not disorders with frenzy as in the case of aniline — lowering of blood pressure and of temperature, cold and damp skin, and weakness and early slowing of the respiration with passing dyspnoea.

During experiments on animals a definite action on the spinal cord with increased excitability of the reflexes has been observed. Paraesthesia and hypoaesthesia have also been noticed, sometimes sensory, such as disturbances of vision, sensation of deafness, tickling, and feelings of pins and needles in the
limbs, which are symptoms due to effects exerted on the peripheral nerves.

When the poisoning has a slow chronic development, parenchymatous lesions of the organs are sometimes observed, particularly of the liver, with the clinical picture of an acute atrophy of that organ which may terminate in death. But these lesions are only rarely observed in man (Walker).

The fatal acute dose is 0.1 grm. per os for the rabbit (Röhl), 0.08 grm. for the dog (dead at the end of six hours). With regard to absorption by the skin, 0.4 grm. per kilo is rapidly fatal for the cat (Dambloff). The result is also fatal when, for five consecutive days, 0.1 grm. of an ointment made with vaseline containing 5 per cent. of dinitrobenzene is smeared on (Ettlinger).

In man two rubbings with 0.1 grm. of m.-dinitrobenzene, applied in the form of an ointment made with lanoline, cause clearly defined signs of poisoning.

Autopsies of fatal cases from acute and subacute poisoning show, besides the changes in the blood already noted, fatty degeneration of the organs, passive congestion of the liver, petechial haemorrhages sub-pleural and under the mucous membrane of the digestive organs, and casts of haemoglobin in the loops of Henle.

From the point of view of industrial hygiene, it is interesting to note that absorption of alcohol, in the same way as occurs for such other poisons as nitro and amino aromatic derivatives, facilitates and considerably intensifies the symptoms. Further, according to experiments on animals, it seems that when the poison is administered per os, absorption is greatly facilitated by the simultaneous ingestion of alcohol. But as regards occupational poisoning in man, this fact is scarcely worth considering. Still, as was first remarked by Möhr, absorption of alcohol later may provoke a violent outbreak of poisoning. One is inclined to look for the cause of this in the mobilisation of poison accumulated on the outside of the deposits of fat.

An endeavour has been made to explain this greater rapidity in poisoning, this greater reduction of nitrophenylhydroxylamine, by acceleration of the cell respiration which the absorption of alcohol causes (Lipschitz).

The dinitrotoluene causes generally the same reactions, particularly as regards the formation of methaemoglobin, but experience acquired in the domain of industrial hygiene in the form of the atrophy resulting from experiments on animals show that they are much less toxic. This fact rests perhaps on a tendency to recover from poisoning, due to oxidation of the methyl group.

Dinitrochlorobenzene also seems to be less toxic. Chilian, during experiments on animals with this product, was only able to cause poisoning by administering alcohol simultaneously. On the other hand, as used in industry the 1-chloro-2,4-dinitrobenzene produces on the skin an extraordinarily acute irritation which shows itself, especially in the case of sensitive persons, even on contact with only scant traces of this product, by extensive and serious dermatitis.

By reduction of the corresponding DNBrns, nitranilines (C_6H_4 NO_2 NH_2) are obtained. Paranimaniline is a yellow crystalline powder, which is dissolved with difficulty in water, but, on the contrary, is readily dissolved in alcohol and ether. Its melting point is 147° C. The ortho crystallises in orange yellow coloured needles; its melting point is 71.5° C.; it is dissolved with difficulty in cold water, but quite easily in hot water and easily in alcohol and ether.

According to Lehmann, a cat can absorb 0.3-0.5 grm. without other sign than a momentary methaemoglobin-aemia. When taken on an empty stomach, 0.2-0.3 grm. causes death in animals with trembling, paralysis and comas. When applied on the skin it only causes death if used in strong doses. In the urine are found haemoglobin, bilirubin and often small quantities of paranitraniline.

Statistics

Even though prepared and handled with all necessary precautions, dinitrobenzene has caused on all sides numerous cases of poisoning, often fatal, particularly in munition factories during the war.

In Germany it was found from 1914 to 1918 that in certain cases it was not possible to determine the part due to poisoning and that due to other injurious causes, other than occupational. It was no longer possible to exclude women from factories where DNB was handled for filling projectiles, although the low resistance of women workers to the action of the poison was obvious.

The following figures are significant. In a factory at Luneburg, during four months in 1918, out of 200 workers, of whom 50 were women, 68 cases of poisoning were observed, with 756 days of sickness. In factories of the Ober Pfalz district, during twelve months, 1,075 women, 2.87 per cent. of women workers were poisoned by DNB. At Magdeburg 28 per cent. of the workwomen of a factory were affected by poisoning, while men were only affected in the proportion of 16 per cent.
Without doubt individual predisposition plays a large part: due to being too young or too old; or to existing poisoning by alcohol, tobacco, or lead; or to such infections as syphilis. But heat more than anything increases the incidence of the poisoning; hence its summer prevalence.

The health conditions of workers in contact with DNB are shown in the tables below.

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean working complement for 300 days or working posts</th>
<th>Cases of sickness per 100 workers</th>
<th>Cases of sickness from nitro compounds</th>
<th>Deaths from nitro compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>1916</td>
<td>1,018</td>
<td>6.4</td>
<td>112</td>
<td>3</td>
</tr>
<tr>
<td>1917</td>
<td>1,024</td>
<td>9.5</td>
<td>201</td>
<td>7</td>
</tr>
<tr>
<td>1918</td>
<td>1,490</td>
<td>8.5</td>
<td>130</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>335 women in the section</td>
<td></td>
<td>Out of the total of 443 persons only 165 men</td>
<td>Out of the total of 13 persons only 3 men</td>
</tr>
</tbody>
</table>

**STATISTICS OF SICKNESS AMONG WORKERS IN CONTACT WITH AROMATIC NITRO COMPOUNDS (POTSdam)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Diseases</th>
<th>Men 1916 - 145</th>
<th>Women 1916 - 380</th>
</tr>
</thead>
<tbody>
<tr>
<td>1917</td>
<td>Skin</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Respiratory passages</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Digestive organs</td>
<td>9.7</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>Blood vessels</td>
<td>10.5</td>
<td>10</td>
</tr>
<tr>
<td>1918</td>
<td>Skin</td>
<td>100</td>
<td>121</td>
</tr>
<tr>
<td></td>
<td>Respiratory passages</td>
<td>232</td>
<td>28.7</td>
</tr>
<tr>
<td></td>
<td>Digestive organs</td>
<td>203</td>
<td>394</td>
</tr>
<tr>
<td></td>
<td>Blood vessels</td>
<td>4.1</td>
<td>661</td>
</tr>
<tr>
<td></td>
<td>Jaundice</td>
<td>1.5**</td>
<td>7</td>
</tr>
</tbody>
</table>

* Two deaths in the 1.2. ** Five deaths in the 1.5.

**STATISTICS OF SICKNESS AND DEATHS AMONG THE WORKERS OF AN EXPLOSIVES FACTORY WHO WERE EMPLOYED IN CONTACT WITH DINITROBENZENE (DUSSELDORF)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of workers</th>
<th>Cases of sickness per 100 workers</th>
<th>Days of sickness per worker</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>1912</td>
<td>Men 550</td>
<td>69.0</td>
<td>14.0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>63.0</td>
<td>18.0</td>
<td>2</td>
</tr>
<tr>
<td>1913</td>
<td>Men 590</td>
<td>83.0</td>
<td>13.0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>5.5</td>
<td>12.0</td>
<td>3</td>
</tr>
<tr>
<td>1914</td>
<td>Men 686</td>
<td>82.0</td>
<td>12.0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>130</td>
<td>5.6</td>
<td>4</td>
</tr>
<tr>
<td>1915</td>
<td>Men 1,003</td>
<td>94.0</td>
<td>7.0</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>710</td>
<td>12.0</td>
<td>12</td>
</tr>
<tr>
<td>1916</td>
<td>Men 1,516</td>
<td>56.7</td>
<td>11.0</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>873</td>
<td>13.0</td>
<td>1</td>
</tr>
<tr>
<td>1917</td>
<td>Men 1,998</td>
<td>89.0</td>
<td>11.0</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>550</td>
<td>13.0</td>
<td>8</td>
</tr>
<tr>
<td>1918</td>
<td>Men 2,059</td>
<td>105</td>
<td>18.0</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>909</td>
<td>26.0</td>
<td>3</td>
</tr>
</tbody>
</table>

**STATISTICS OF SICKNESS AND DEATHS AMONG WORKERS IN CONTACT WITH DINITROBENZENE AND TRINITROANISOL IN AN EXPLOSIVES FACTORY AT DUSSELDORF**

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of workers</th>
<th>Cases of sickness per 100 workers</th>
<th>Days of sickness per worker</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>1912</td>
<td>Men 407</td>
<td>40.0</td>
<td>5.0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>16</td>
<td>12.5</td>
<td>7.0</td>
</tr>
<tr>
<td>1913</td>
<td>Men 478</td>
<td>47.7</td>
<td>6.0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>24</td>
<td>12.5</td>
<td>7.0</td>
</tr>
<tr>
<td>1914</td>
<td>Men 1,480</td>
<td>25.0</td>
<td>3.1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>251</td>
<td>20.3</td>
<td>1.5</td>
</tr>
<tr>
<td>1915</td>
<td>Men 1,650</td>
<td>55.2</td>
<td>5.6</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>535</td>
<td>10.0</td>
<td>3</td>
</tr>
<tr>
<td>1916</td>
<td>Men 1,641</td>
<td>47.6</td>
<td>6.1</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>735</td>
<td>6.4</td>
<td>7</td>
</tr>
<tr>
<td>1917</td>
<td>Men 2,055</td>
<td>57.7</td>
<td>7.6</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>692</td>
<td>41.7</td>
<td>8.8</td>
</tr>
<tr>
<td>1918</td>
<td>Men 1,911</td>
<td>55.0</td>
<td>8.4</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>886</td>
<td>42.4</td>
<td>8.2</td>
</tr>
</tbody>
</table>

1 The Sickness Funds from the date of 1 January 1915 up to the end of the war received certificates of 1,000 cases (some slight, duration five days) with 12 deaths.

In a factory which employed 130 workers (mean working complement — 123), from December 1916 to October 1918, out of a total of 68,767 working days and an average of 195.6 working posts, there were 340 cases of poisoning, or 864.3 per 100 working posts, and a monthly average of 14.7 cases, or 12.2 per 100 working posts.

In another factory employing 816 workers (mean working complement — 123), from December 1916 to October 1918, out of a total of 17,756 working days and 88.7 working posts, 314 cases of poisoning were reported, or 323.7 per 100 working posts with a monthly average for the workers of 30.2 or 44.2 per 100 working posts — four times greater than in the preceding factory.
In 1919 one fatal case was reported in Hesse and two serious cases in Bavaria; in 1920, 78 cases in Bavaria, where in 1921, 60 further cases were reported. It is certain however that most of the cases were not notified. In 1921 in Saxony 9 cases were known, chiefly by causing incapacity from 3 to 15 days. In Prussia, from 1920 to 1922, 13 cases were reported from Frankfort-on-the-Oder and 15 cases from another factory of the same district. 3 of which were fatal, from the district of Köslin; and 31 cases from the district of Potsdam. In 1922, some cases of poisoning were found among agricultural labourers employed in felling trees by means of an explosive mixture made up of 60 per cent. DNB and 40 per cent. TNT, a mixture which had to be crushed by hand.

In Bavaria dinitrochlorobenzene caused 32 cases of dermatitis in 1919. Cords in 1918 reported among munition workers several cases of ocular lesions characterised by ambioplia, as well as cases of damaged hearing, due to DNB.

In 1923-1924, the incidence of poisoning was much less. As a matter of fact 6 cases only were reported in the Potsdam district, and 6 in that of Liegnitz, in every case in explosives factories.

In 1926, 2 cases occurred in a chemical products factory at Löneburg.

In the United States DNB was the only compound which, during the war, caused numerous cases of poisoning in munition works (Hamilton). Not less than 50 per cent. of all the cases of sickness reported among the workers at munition works were due to DNB.

In Switzerland from 1917 to 1918, 47 cases of poisoning were known, with 654 days of sickness. In 1918 the Insurance Office for the district of Aarau received 36 notifications of poisoning by DNB.

As regards other countries, cases of poisoning by DNB are included with those due to nitro and amino compounds of benzene and its homologues (see that article).

**SYMPTOMS**

It is necessary to distinguish acute poisoning with a rapid development, from the slow form, which develops progressively under the influence of prolonged work, and from the chronic form. There is frequently present an acute exacerbation supervening on chronic symptoms already existing, so that the picture of symptoms presented is mixed.

**Acute Poisoning**

First, acute poisoning is caused chiefly by the rapid absorption of the poison through the skin. Without any long latent period, an attack may occur in the space of twenty-four hours with serious symptoms leading to a fatal issue. The premonitory symptoms, that is to say, the initial manifestations are: headache, vertigo and vomiting; serious symptoms affecting the nervous system and the blood, which make an early and rapid appearance. Depression and a paralysing action are predominant, ending in weakness with great exhaustion, a staggering gait, and, at quite an early stage, somnolence and loss of consciousness. Profound cyanosis develops at the same time with a bluish-grey coloration which is especially marked on the lips, the mucous membranes, and at the extremities of the fingers. The skin is moist and cold. The patients complain of sensations of itching, numbness and tickling, localised to the limbs, of floating specks and cloudiness of the visual field. At first respiration is deeper and quicker; the pulse is weak and frequent, often unequal, and the blood pressure is diminished. In serious cases the cyanosis rapidly increases and the blood is dark brown; the cerebral disturbances increase, and a delirium with complete loss of consciousness supervenes; the dilated pupils react sluggishly; respiration is slow, then becomes intermittent and superficial; the temperature falls; the heart weakens; and, at the end of twenty-four hours, death may occur from asphyxia with paralysis of respiration, and sometimes with spasms of immediate asphyxia.

If acute poisoning terminates in recovery, the symptoms remain much longer than in poisoning by nitrobenzene and particularly by aniline. Cyanosis, weakness and vertigo persist in slight cases for several days and only disappear after a long time.

In serious cases, changes in the red blood corpuscles appear from the first days and lead in a short time to marked anaemia with diminution in the red cells accompanied by leucocytosis (see above under Toxic Effect, p. 569). As the result of the destruction of the red blood corpuscles a speckled chronic jaundice ensues, which often occurs even in the presence of cyanosis. Sometimes a slight enlargement of the liver is observed which is sensitive to pressure. When recovery is slow, the general health is constantly troubled by a sensation of weakness, by loss of appetite, by vertigo and the sequelae of anaemia. During the first days of the poisoning the urine is scanty, generally of a deep colour, which becomes darker on exposure to air; for several days m.-nitraniline may be detected in it (see later under Detection, p. 574). The urine contains in addition derivatives of haemoglobin, notably a large quantity of urobilin, of haemato- porphyrin (Möhr), and of bile pigments; albumen and casts are rarely found in
the primary stages of serious acute poisoning.

**Subacute and Chronic Poisoning**

In these forms secondary anaemia is the prominent feature in the clinical picture, exhibiting diminution in the haemoglobin and in the number of red cells, and generally a temporary, but definite, appearance of the elements of regeneration — polychromasia, megaloblasts, and myelocytes.

The anaemia may progressively reach an advanced degree with diminution, to as much as a half, in the normal amount of haemoglobin and in the number of red cells; but it has, however, the character of a secondary anaemia from the fact of the lowering of the colorimetric index and of the marked leucocytosis, even when microscopic examination shows that nucleated red cells, both normoblasts and megaloblasts, are predominant.

The speckled chloric jaundice is never absent and is often very distinct; it is accompanied for a long time by pronounced cyanosis which lasts after the cessation of work much longer than in the case of poisoning by nitrobenzene and aniline. The skin assumes a particular colour, due to the superimposition of the yellowing of the sclerotics, and of a pronounced diffuse cyanosis on the cheeks, lips and ears; in contrast this tint is a true pallor, slightly jaundiced, such as is met with in chronic poisoning by nitrobenzene. Methaemoglobin, which disappears rapidly in nitrobenzene poisoning when work is stopped, can be detected much longer in poisoning by dinitrobenzene.

Subjective troubles are more tendacious than in other poisonings by nitro and amino derivatives; they should be considered partly as the result of anaemia, but partly also as an expression of the direct action of the poison on the nervous system. These troubles are as follows: general wasting away; weakness and fatigue; headache with the onset of vertigo progressing to a staggering gait; a tendency to palpitation and to shallow breathing; malaise; vomiting; loss of appetite and gastric troubles; emaciation and loss of strength. Quite often affections confined to the peripheral nervous system are also noticed. These are indicated by sensitive and sensorial hypoesthesia and paraesthesiae; by a feeling of numbness and pins and needles in the limbs, with even slight ataxic conditions; by weakening of the sight, clouding and diminution of the visual field, scotoma and amblyopia; by motor disturbances which take the form of slight pareses, notably in the area supplied by the cranial nerves, setting up disorders of vision, diplopia, nystagmus, and disorders of the pupillary reflexes.

When the jaundice is very deep, enlargement of the liver can be detected and a slight tenderness in this region on pressure, due to biliary stasis. Rarely parenchymatous lesions of the liver are present, a condition which seems more liable to occur among women. In serious cases it leads on to death with a clinical picture of acute atrophy.

The development of subacute and chronic poisoning by dinitrobenzene is always slower than that of chronic poisoning by aniline and mono-nitrobenzene. In the same way, the tendency which the symptoms from these poisons exhibit of becoming chronic is much stronger than with dinitrobenzene.

The duration of the sickness often exceeds several weeks, and even after this lapse of time general weakness remains with anaemia and a series of disorders and subjective symptoms, notably of a nervous type, which persist a long while.

**Detection**

In the Urine

Contrary to the opinions previously held by Huber and White, dinitrobenzene is not found in the urine unchanged; but the major part at least is in the form of m.-nitraniline. This body may be detected either qualitatively by direct nitration of the amino group and combining it with naphthol, which gives rise to the formation of a red nitric colouring material; or, a more accurate method, by preliminary reduction with tin and hydrochloric acid into m.-phenylendiamine which by nitration with acid gives directly Bismarck brown. These reactions may be carried out either on urine itself, or, in a more sensitive way, on an ethereal extract from urine taken up by alcohol or water, or yet again on the distillate of this extract. The urine, the extract or distillate are slightly acidified with hydrochloric acid; then some drops of a solution of nitrite of soda are added and the mixture is set in a cool place; after neutralising with a solution of soda and the addition of a small quantity of a solution of alpha naphthol, a red coloration appears.

This reaction only proves the presence of an amino group in the nucleus; for it is also positive, by saponification of the combined sulphuric acid, in the presence of amidophenol in the urine, from poisoning by aniline or nitrobenzene (heating with hydrochloric acid). The presence of m.-nitraniline or of unchanged dinitrobenzol, to the exclusion of m.-phenyl-
endiamine is proved in a more specific and more certain way by a second method of testing: reduction by tin and hydrochloric acid in the cold state, followed by neutralisation with a solution of soda and mixing the filtrate with some drops of a solution of nitrite of soda. Thus quite distinct coloration is obtained, yellow changing to brown. By carrying out this reaction on an ethereal extract, or on a distillate, in the presence of a weak alkaline reaction, the test can be applied to organic materials.

**Prophylaxis**

The most important points in the prevention of poisoning by DNB are (i) to combat careless and dirty habits, and (ii) to catch steam containing dinitrobenzene during the manufacture and use of this product. In the first place the factory and plant must be thoroughly up to day both from the technical and hygienic point of view. Tanks for nitration and reduction, in case of subsequent manipulations, should be provided with hermetically closing doors for charging, with refrigerants to prevent back flow, and with adequate apparatus for the removal of fumes. Care must be taken to exhaust and remove all fumes given off when the residuary acid is drawn off, when dinitrobenzene is washed with hot water, when the water used for washing and the finished product are run off, and, lastly, when this product is melted and solidified.

While the product is being washed in filtering tanks and the hot water used for washing is being discharged, the tanks should be supplied with wooden covers; in the same way, closing of the crystallisation tanks should be insisted on during solidification.

When it is a question of organising a factory that is perfect from the technical and hygienic points of view, it is extremely important to install such free natural ventilation that it is effective, thanks to its construction, for meeting every emergency. As a matter of fact it is not always possible by artificial ventilation alone to catch and remove all steam containing dinitrobenzene, especially at the washing tanks.

Working platforms and platforms carrying apparatus should not obstruct natural incoming currents of air, and the working platforms should only occupy a small part of the floor.

Doors and windows should be numerous and arranged in such a way as to ensure abundant ventilation. The roof should be fitted, with the same object in view, with a louvre of adequate dimensions.

Often all these arrangements intended to ensure natural ventilation, even when supplemented by artificial ventilation, are not sufficient to overcome the agencies prejudicial to health. They fail chiefly in summer and on windless days, when the heat is oppressive; it is not uncommon on these days to see the whole personnel of dinitrobenzene factories affected with slight cyanosis and other symptoms of poisoning. It is for this reason that the buildings are sometimes completely open on the whole of one side, or are simply protected by a partition of a certain height which does not reach up to the roof or down to the floor, and so provides a free space for aeration.

In German works used for breaking up munitions, the workshops for removing the fuses have to be arranged on a raised platform, open on all sides and exposed to the open air. The success of this method shows how important is the role of dinitrobenzene, easily carried by steam, in the development of poisonings. In several works production is limited as far as possible, or for the time being completely suspended, during the hot season, at any rate so far as the raw materials already in hand make this permissible.

All flooring, in order to facilitate satisfactory cleaning, should be made of an impermeable material, and should be quite even, and preferably with a fall towards a drainage channel. It is useless to asphalt or tar the floor, for these materials allow dinitrobenzene to penetrate and accumulate there.

By reason of the great importance of absorption by the undamaged skin, notably in the development of acute poisoning, it is necessary to avoid all regular contact by the workmen with the product, as well as any resulting soiling, and to provide the workers with opportunities for cleaning themselves regularly during work and after.

"Granulated" dinitrobenzene should be moved from filtering tanks and drying chambers to receptacles for melting as far as possible by automatic means, that is to say, by an endless screw or a chain of buckets. Workmen should wear during work suitable impermeable overalls closed at the wrists and neck. Impermeable gloves and boots are of great use. Working garments must be changed and cleaned regularly as soon as soiled by the poisonous product; in large works cleaning is done by benzol or alcohol. This cleaning is especially needed for gowns, which are easily soiled. Eventually, when the garments have been soiled more than usual, they must be changed.
at once and a bath taken. It is equally essential to remove the working clothes and see that the hands are washed before taking a meal, and to provide dining-rooms, cloak-rooms, and baths with baths.

The workman should be instructed as to the poisonous nature of the product and as to the necessity for observing bodily cleanliness, as well as with regard to the dangers associated with taking alcohol, which should be forbidden in the works.

On account of the frequency of subacute and chronic poisoning, medical supervision in factories where dinitrobenzene is handled is of great importance and stricter than in the factories, where work on nitro or amino derivatives is carried on. It is advisable to have oxygen apparatus handy, and adequate arrangements made for the immediate treatment of acute cases.

**Legislation**

Detailed regulations governing the erection and working of factories for the manufacture or the recovery of the aromatic nitro and amino derivatives, which affect also the preparation of dinitrobenzene, have been drawn up in Prussia by the Decree of the Minister of Commerce and Industry of 21 October 1911, and in Bavaria by the Ministerial Decree of 16 November 1911. (For further details, see article "Anilines"). These Decrees contain very detailed rules on the construction and equipping of the factories, as well as on the installation of hygienic methods of manufacture of hygienic measures designed to prevent the liberation of fumes and dust and on risks from soiling, depending on handling the products. Workers are to be particularly advised as to the toxicity of the products handled, and as to the danger from abuse of alcoholic drinks; and these warnings should be given not only when the workers are engaged but several times a year. Suitable working clothes must be provided. Smoking and taking alcohol during work is prohibited; dining-rooms, cloak-rooms, lavatories and baths are provided. Oxygen apparatus must be provided and its use explained to the foremen.

The employment of women and children is prohibited. Male workers over eighteen years may be admitted, but they should, before being engaged, be medically examined by a doctor appointed by the competent authority and be furnished with a certificate of fitness.

A periodical examination of all workers should be made every four weeks.

Diseases caused by dinitrobenzene are compulsorily notifiable in Germany (in Bavaria since 1912); they must be compensated according to the Act of 12 May 1925 relative to the alleviation of occupational diseases to accidents for the purposes of compensation. Compulsory notification is also laid down in France, Netherlands and several States of the United States of America. Compensation is granted in Austria, Canada, Finland, Germany, Great Britain, Italy, Western Australia, Queensland, Minnesota, New York, New Jersey, Ohio, Porto Rico, Switzerland, Venezuela, and in countries in which injury from aromatic nitro and amino derivatives is compensated. (See also articles "Benzene Derivatives", "Nitro and Amino Derivatives", "Industrial Diseases: Compensation").

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**Dinitrophenol**


**Properties**

Dinitrophenol is a substitution product resulting from the nitration of phenol; it is one of the members of a chemical series of dinitrated phenols. The general formula is \( C_6 H_2 (NO_2)_{2} OH \); and there are theoretically six isomers, according, with the positions in the ring of groups NO, and OH.

Ordinary dinitrophenol obtained in manufacture is the isomer 1,2,4; it is distinguished from the others by special properties, notably its high toxicity.

It is a crystallisable, yellow or yellowish-white, solid substance, having a slight smell of phenol; it melts at 111°C., and boils at 114°C., if pure. While scarcely soluble at all in cold water, only 1 part in 1,000 of water, it is very soluble in warm water, in alcohol, ether, benzene and chloroform. It is easily sublimed, and is easily carried by steam (1 kg. of steam carries 3 grm.).
INDUSTRIAL PROCESSES

It is prepared commercially by nitrat- ing pure monochlorobenzene. In the first phase dinitrochlorobenzene is obtained. The product is granulated, centrifuged, and, while still moist, is brought to the boil in an iron boiler equipped with a stirrer, together with carbonate of soda and water; the solution is then poured into dilute sulphuric acid, when the pure DNP is separated in granulated form. It is washed till it is no longer acid, left to dry, and then desiccated with hot air. DNP is deposited on tables in drying rooms, where the desiccation continues, before being put in barrels, weighed and despatched.

When reduced by tin and hydrochloric acid, it gives p.-diamidophenol or amidol.

In use it is subjected to various processes, such as melting in the preparation of explosive mixtures, or for pouring charges into shells. During the war it was used as an explosive. Timber, for purposes of preservation, is now impregnated with it; but it is chiefly used for making sulphur black in the dye industry.

SOURCES OF DANGER

These present a very important practical problem, as most of the acute forms are fatal.

(1) During its manufacture.—Poisoning occurs almost exclusively in the drying and conditioning rooms, associated with preparation for delivery, and putting DNP into sacks or barrels. During drying the rapid revolutions of the centrifuges generate a liquid spray holding DNP in suspension; this process is all the more dangerous as the apparatus may not be absolutely hermetically closed. During conditioning, the atmosphere of the workshops, where thousands of kilograms of the substance may be manipulated, becomes charged with emanations and poisonous dust.

(2) During its use in industry.—The melting of DNP is a dangerous operation on account of harmful fumes which are set free as steam containing DNP in suspension.

The cleaning of empty barrels which have contained DNP has also caused poisonings, according to Quignard.

As sources of hazard, various chemical products used in the manufacture, or which may be formed during industrial operations, must also be noted. Thus, for example, when the distilling apparatus is emptied of chloroanisole, poisoning may result from this substance or from polychloro-compounds of benzene.

TOXIC ACTION

It may be said that it was the experience gained by the French during the war which called attention to the characteristic action of DNP 1-2-4, about which nothing had been known until then, although this substance was reported to have a toxic action identical to that of other isomers. Its toxicity was all the more easily overlooked in that, before the war, only a few kilograms a day were handled in the manufacture of sulphur black, in contrast with thousands of tons in explosives.

The researches and experiments made in France by A. Mayer, following upon the occurrence of numerous cases of poisoning, showed that DNP has its own peculiar toxic properties, quite independent of the presence of impurities to which the toxicity was at first ascribed.

As a matter of fact, both pure DNP and crude or commercial DNP have caused the same symptoms of poisoning.

DNP acts as an excitant of general intracellular metabolism. An injection of a fatal dose causes in animals a considerable increase, from ten to twelve times the normal, in the gaseous exchanges, with asphyxia of the cellular tissues, which, however, is neither directly nor indirectly due to stimulation of the nervous system, nor to any increase of muscular work, nor to any action of the poison on any particular organ. In the dog, heat polyphagia is observed; in horses cutaneous vaso-dilatation; in these animals, there are profuse sweats, and, in spite of this reaction to ensure an increase in the activity of heat radiation, a considerable rise of temperature occurs which, after death, may reach $45^\circ C$.

The general increase in oxidation reacts on the general phenomena of nutrition as well as on certain organs.

1 These poisonings differ from those due to DNP, as they are characterised by violent colic with profuse diarrhoea and amnesia, and by breath of a characteristic smell; they are generally harmless and disappear after a few hours rest.

2 Bauermann and Hertel studied the elimination in the urine of nitrophenol without mentioning its toxicity: Gibbs and Hare, in 1889, fixed the fatal dose of ortho-nitrophenol at 0.1 grm. per kilo of the animal; at 0.053 for the meta and at 0.091 for the para isomer. These authors noticed the characteristic effect of the substance on the central nervous system.
DINITROPHENOL

such as the liver and kidneys, the functions of which are disturbed, both cytologically and chemically. Lehmann admits an action of mono- and of nitrophenol, which are soluble in lipoids, on the central nervous system, as well as a special affinity of these products, with the exception of the ortho-nitrophenol, for muscular tissue.

Non-fatal doses cause general symptoms which are not very definite, but their action is equally apparent on the general nutrition and the kidneys.

Experiments, however, have not furnished knowledge as to the mode of the poisoning, the pathogenesis of which is not definitely well known.

For all kinds of animals the poisonous doses are very small. According to Mayer, DNP is usually fatal in a dose of 0.01 grm. per kilo of animal weight in the dog, rabbit and pigeon; in a dose of 0.02 grm. per kilo in the horse. Koelsch has caused death in cats after exposure for one hour and a half to doses of 0.05 per kilo; in 53 days to doses at first of 0.005 and later of 0.01 grm. per kilo.

According to Lehmann and L. Schmidt Kehl (1927), cats can tolerate 100 mg. of para-nitrophenol; about 200 mg. of ortho-; about 20 mg. of ortho-paranitrophenol; and about 20-25 mg. of diortho-nitrophenol per kilo of animal. Death supervenes when the dose is increased by a quarter. The sensitiveness of animals is increased by the administration of alcohol. The experiments of the British Committee (1918) showed that the ingestion of 160 mg. of DNP per kilo, as well as a subcutaneous injection of 90 mg., caused a fatal issue.

Heat seems to play a favourable rôle, for the cases of poisoning occur almost exclusively in the summer during very warm days, and especially in the conditioning department. The incidence diminishes with the suppression of day work in summer. Among predisposed workmen, in a fair way of, or in actual danger of, toxic absorption, heat seems to be an occasional factor in the poisoning, but the details of reaction are not well known, in spite of the hypotheses put forward, such as partial sublimation of the poison, deficient functioning of the liver and kidneys, or chemical intracellular reactions.

The influence of alcohol on the development of toxic phenomena in man is very definite. Poisoning cases are more numerous the day after a holiday and among confirmed alcoholics who ought to be removed from the workshops. It is chiefly among alcoholics that the fatal poisonings reported by Etienne Martin have occurred.

This authority has reported phenomena due to predisposition, related to methods of work, and of wearing clothes, to the condition of the skin, or of perspiration. Workers on DNP, placed under identical conditions of work, were not all affected alike. Some showed a marked predisposition and a more or less definite tolerance; others, again, a real immunity (Quignard). During the war women employed in France in manipulating DNP or mixtures containing this explosive, seemed to be much more resistant than men; it is true that they were worked at the time in the open air (Frois).

Absorption of the poison is facilitated by its volatility and also by its solubility in the fluids of the body.

The existence of a cumulative action has not been established; on the contrary, it appears possible that workers may become accustomed to it (Lehmann).

Entry into the body may take place through the respiratory passages by inhaling the products of atomisation, generated during drying; or dust, generated during conditioning; or fumes from melting. Or it may occur by the alimentary canal through the ingestion of dust, or through the skin by direct contact. DNP passes through the skin very easily, especially if it is moist or sticky with sweat. Experimentally, however, the skin requires a dose ten times greater than by the sub-cutaneous path. Absorption is facilitated by the presence of fatty substances (Lehmann). The most scrupulous cleansing never frees skin impregnated with DNP from its yellow tint, which betrays the fact that poisonous particles remain in the skin; and that absorption, however slow it may be, is continuous. The areas selected are the uncovered parts—face, neck, forearms, but chiefly the palms of the hands and the soles of the feet.

The clinical picture does not show that the seriousness of the poisoning is a function of the path of entry. Indeed, the invasion can actually take place by three paths simultaneously. This agrees with the experimental evidence which has shown that, whatever be the path of entry for the poison, whether by injection (intra-tracheal, intra-venous, or subcutaneous), or by ingestion (by stomach tube), or by painting the skin, the experimental poisoning caused exhibits the same symptoms.

In spite of the research work that has been carried out it has not yet been possible to establish the mechanism which controls the total or partial transformation of DNP in the body. But
there has been found when carrying out some autopsies on the bodies of victims, either untransformed DNP in the blood and in the organs, with products of reduction in the urine, or DNP in a pure state with products of reduction throughout the whole system. In one case, reported by Lehmann, a substance with a yellow colour having the reaction of picric acid was found in the body.

However that may be, DNP is passed out in the excreta and chiefly in the urine, which take on a peculiar deepish orange yellow colour. Investigations, based on colour reactions, have shown that DNP is regularly eliminated as such, and also in the form of reduction products formed under conditions which are still obscure and include, according to their state of reduction, the following bodies:

(a) Aminonitrophenol. This body is always in abundance in subjects who are in a state of toxic impregnation, as well as in all poisoning cases which are recognised clinically. The amount present appears to be in proportion to the degree of poisoning. It is eliminated in about the space of a week, and, in favourable cases, in twenty-four hours (Mayer), depending upon the influence of such various factors as the quantity absorbed, individual hygiene, the protective power of the body, and the functional state of the liver and kidneys.

(b) Diaminophenol. The elimination of this body, as that of unaltered DNP, is not accompanied by any special symptoms of intolerance.

c) Nitric compounds. These are intermediary products between nitrobenzene and aniline.

These various bodies are detected by definite chemical reactions (see further on, under Detection).

STATISTICS

In France, during the war, up to August 1916, 27 fatal cases occurred in seven factories, 17 of which were during weighing and melting processes, and 8 during dessication, 1 from stove drying, and 1 from conditioning; there were also many mild cases. In his thesis, Quirold reports 11 cases of poisoning, 2 of which were fatal, between 28 June 1916 and 2 August 1917; 7 cases, 1 of which was fatal, occurred at the desiccators; 2 cases, of which was fatal, in the conditioning process; 1 case in the cleaning of empty barrels; and 1 case is without any indication of origin.

Some cases of poisoning were reported in Germany in 1901 by Keibel; in 1902 by Levy, as well as by Leymann who reported three fatal cases during the preparation of sulphur black from DNP. In 1914-1918, in the Oppeln district a case of general eczematous dermatitis due to DNP was reported in a workman employed in impregnating wood. A fatal case reported by Lehmann was the subject of an article in 1927 (see bibliography at end of article).

In Great Britain, several cases, of which one was fatal, occurred during manufacture from 1916 to 1918; but the report of the Medical Inspector recorded in 1919 several cases of ill-health among workers in DNP factories.

In Switzerland 2 cases were noted in 1922.

In the United States, Hamilton reported 3 fatal cases in a melinite factory during the war. A fourth case which was not fatal, was attributed to DNP, but it was not certainly due to this substance, for the symptoms were those of poisoning by TNT.

SYMPTOMS

Poisoning occurs in three forms:

First, a slight form with mild poisoning, characterised chiefly by: lassitude, slight headache, night sweats, perspiration and fatigue on the least exertion, temperature nearly normal (scarcely reaching 38° C.), and the presence of aminonitrophenol in the urine.

Associated and accessory symptoms are gastro-intestinal disorders which sometimes seem to be the most important; a dirty tongue; loss of appetite; nausea; vomiting; and intestinal colic with diarrhoea. Buzzing in the ears may be present, and vertigo, with a regular pulse at 75-80.

Second, a subacute form with moderate poisoning, which begins with a painful sensation of oppression, general malaise, with dazed feelings, vertigo, tinnitus, sometimes faintings, congestion of the face, slight but persistent dyspnoea. The pulse is rapid, about 100, but regular and strong. The temperature reaches and may even exceed 39° C. Complete anorexia is present with great thirst, copious perspiration, and constant restlessness. The mucous membranes are not injected and the reflexes are normal. The respiratory organs show signs of pulmonary congestion. Urine is abundant, of the colour of strong tea, changing rapidly to a blackish tint, greenish on reflection; the only other reactions it exhibits are due to the presence of aminonitrophenol.

Third, a serious form with very acute poisoning; it starts suddenly whilst at work with a general malaise which is characteristic, accompanied by constriction of the chest which feels rigid as a bar or as if in a vice, and by extreme weakness. Dyspnoea is intense, pre-
venting speech; the face is flushed; the lips are cyanosed; pupils are dilated; the pulse at 120-130 is very strong and bounding. There are signs of pulmonary congestion. The urine is scanty; sometimes its colour is clear mahogany, sometimes deep orange-yellow; and it contains large quantities of aminonitrophenol. The thirst is intense; and sweating is so profuse as to form a bath of sweat. The temperature reaches 40° C. and over; and some cases have been noted where it has continued to rise after death. The state of anxious terror and the restlessness of the patient are typical; he yields himself to a succession of continuous movements which do not allow him any rest. After two or three hours the death coma comes on with or without contractures. Sometimes there is a temporary improvement with remission of symptoms which only gives way to the final syncope. Death appears to be due chiefly to congestion — to pulmonary congestion, as well as to cerebral congestion.

In these three types a yellow colouration of the skin of the uncovered parts is observed, which has a simple value as an indicating sign.

When the dose is not fatal, the morbid symptoms improve, and it is recognised that a certain degree of acclimatisation against the poison can be established, but it is rare. The great majority of workmen do not eliminate the poison, and become its victims, if they are not withdrawn from the work in time (Frois).

Emaciation, noticed by workers, as dating from the time of their entrance to the factory and attributed by them to DNP, does not seem to be a sign of poisoning.

**DETECTION**

**In the Air**

It is sufficient to hang threads of white cotton in different parts of the workrooms. If the air contains DNP in suspension, the cotton very soon turns a decided yellow colour.

**In the Body (Urine)**

(a) Derrien's Reaction

To 10 cc. of urine add 1 cc. of 10 per cent. sulphuric acid and 1 cc. of 0.5 per cent. solution of nitrite of soda. It is shaken and allowed to stand for five minutes. To this solution is added 2 cc. of a 0.5 per cent. freshly prepared solution of beta naphthol in ammonia at 22° B. After stirring it is allowed to stand for one or two minutes. Then 5 or 10 cc. of ordinary ether is added. It is stirred and when the liquids separate the colour of the ether is observed.

The reaction is positive, due to the presence of aminonitrophenol, when the colour of the ether is violet, wine-coloured, red, orange, or orange-rose. It is negative when the ether is colourless or orange yellow.

For this ordinary technique a more complicated technique by extraction by ether can be substituted when working with urines containing only traces of aminonitrophenol.

The intensity of the colouration is in proportion to the degree of poisoning and its relative estimation enables an immediate prognosis to be made.

The following confirmatory tests may be carried out.

(b) Meyer's Reaction

(1) Test for dinitrophenol. After clarification of the urine with neutral acetate of lead, in order to eliminate urochromes, the urine is reduced by powdered zinc and sulphuric acid until completely decolorised; it is then filtered. To some cubic centimetres of the filtered urine are added one or two drops of potassium bichromate, 1 in 1,000, acidified with sulphuric acid. When the reaction is positive, there is a rose colouration.

(2) Test for diaminophenol. Reaction with potassium bichromate in an acid reaction: rose colouration.

(c) Seyevetz's Reaction.

This reaction depends on the sensitivity of silver gelatino-bromide paper in the presence of diaminophenol; the degree of blackening of the paper enables the strength of the urine in diaminophenol to be estimated (25 cc. of urine plus 2 cc. of bisulphite of soda). The paper is washed and then fixed with hyposulphite of soda. It is a very accurate qualitative method, but not so useful, from a quantitative point of view, as the estimation of the degree of blackening is a question of interpretation.

**PROGNOSIS**

The prognosis is favourable in the case of mild and medium cases of poisoning, with, however, reservations for the future: it is fatal in very acute cases of poisoning.

Derrien's reaction, apart from the symptoms, may be relied on.

**HYGIENE**

First aid equipment should be provided so that treatment may be given immediately.

Rules of hygiene for the workshop and for the health of the workers should be drawn up.

In addition to general measures of hygiene, such as ventilation, those aiming at diminishing or suppressing the production and dissemination of poisonous emanations must take the
first place: the manufacturing process should be as far as possible automatic; operations should be carried on in closed vessels, with the circulation of chlorohenzene carried on by compressed air pumps; some apparatus should be replaced by others, e.g. drying machines by vacuum filters; localised ventilation is needed, especially where DNP is melted and shells are filled.

Certain regulations in the organisation of the work are particularly of value. Shift work should be arranged so that the shifts alternate from week to week which, by regular rotation, makes it possible for the personnel of unhealthy workshops to be treated and revived by allowing for elimination of the poison. Work by day in some workshops should cease, when the temperature is too high. The daily period of work should be reduced as to prevent fatigue which aggravates the causes of poisoning.

**Personal hygiene.**—Working overalls and underclothing must be worn and masks in certain operations, such as shovelling the product. Cloak-rooms are necessary, with separate compartments for the clothes worn on coming to work and for those worn at work. Sanitary accommodation must be such as to permit of scrupulous cleanliness; lavatories, with hot and cold water, soap, towels, nail-brushes and tooth-brushes should be provided and frequent cleansing of the exposed parts insisted on. Carbonate of soda should also be provided. Smoking must be forbidden, and also eating in the workshops, or taking food into the workshops; there is need for canteens. The personnel should be informed of the dangers of poisoning.

Every worker whose Derrien's reaction remains positive for several days, or increases in intensity, should cease work while he shows signs of intolerance, such as gastro-intestinal disorders, lassitude, sweating, hepatic or renal symptoms. Every workman removed from an unhealthy workshop should only return to work at the end of a week, and after Derrien's reaction is negative. He ought to be discharged altogether if susceptibility returns rapidly.

It is clear that this test, as well as making diagnosis certain, also enables a start to be made in good time upon treatment for elimination of the poison, for arresting the development of symptoms, and, in favourable cases, for preventing the onset of a fatal termination.

**Legislation**

Exclusion of women, children and young persons is laid down by legislation for the derivatives of benzene and its homologues, such as phenols.

Again, the hygienic measures laid down are those prescribed for the nitro-amino derivatives of benzene and its homologues.

Compensation for injuries caused by DNP is provided for by such legislation as has entered in the list of diseases for compensation, the nitro-amino derivatives of benzene and its homologues; and by legislation which defines occupational diseases, as accidents within the meaning of the Acts. DNP is, on the other hand, included in the list of compensable diseases in the British, Swiss Acts and in countries in which injury from aromatic nitro and amino derivatives is compensated.

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(Lyons)
Divers
French: Scaphandriers; Plongeurs. — German: Taucher. — Italian: Polombari.
— Spanish: Buzos.

Unlike work in caissons, the diver’s occupation is of ancient origin — oyster divers being referred to in the Iliad, diving for mechanical purposes by Thucydides, and salvage diving by Livy. The primitive method of such divers is still practised to a great extent by native pearl and sponge fishers at the present time.

Pearl fishers. — Pearl fishing is chiefly engaged in off the Australian coast, amongst the Pacific Islands, in the Gulf of Manaar, the Persian Gulf, the Red Sea, and off the coast of Central America. Boats grouped in fleets of sixty or seventy work simultaneously to the fishing grounds for the season, which lasts about four months. The boats generally leave at midnight to reach the oyster banks by sunrise. Whilst in Australia the divers reach an average depth of four to six fathoms, attaining at times, however, a depth of 120 feet, in the Gulf of Panama the fishing grounds are about 40 feet deep.

A stone weighing 20 kg. is attached to a rope, which the diver holds on descending. The divers work in pairs, one diving whilst the other watches, pulling up first the sink stone, then the oyster basket and finally the diver, who remains on an average fifty to eighty seconds under water. After resting one or two minutes at the surface, the diver redescends and so on until exhausted, when he pulls the signal rope, and off he goes. In 1920, 60 out of 114 medical examinations effected were concerned with admission to the work in question. Of 60 divers examined, a fairly high number presented a parieto-spastic method of walking; 3 of these were the victims of slight accidents in the course of the year. In 1921, amongst the 72 candidates found fit for admission (out of 74 examined) there were found 31 cases of paraplegia; the number of accidents was 4, 3 of which were fatal. In 1922, 123 divers were examined — 85 with a view to admission. Amongst these 85 found fit for work and admitted, there occurred during the year 2 cases of incapacity and 2 accidents (fatal), and on two occasions there were noted the sequelae of cerebral emboli. In 1923, the number of examinations was 111 — 69 of which were with a view to admission; there were 2 cases of fatal accidents.

In 1924, amongst 40 divers passed fit for work, there occurred 2 cases of fatal accidents; in 1929, 3 fatal cases amongst 100 divers. In 1926, out of 158 admitted to work (amongst 170 medically examined), there occurred 13 cases of accidents, 8 of which were fatal.

Divers provided with diving apparatus. — Research having for its object the provision of apparatus which would furnish divers with a supply of air of very ancient origin.

Aristotle and Pliny mention various devices used for this purpose. Progressive attempts at constructing a suitable diver’s dress were made in 1679, 1715, and 1798.

Siebe’s “open dress” obliged the diver to maintain an upright or very slightly stooping position. If he stumbled, water was liable to fill his dress and drown him. In 1850, however, this device was replaced by a “closed dress” by the same inventor, and it is on this model that the modern dress is constructed.
The apparatus comprises various parts: (1) helmet with breast plates; (2) diving dress; (3) heavily weighted boots, and (4) a flexible non-collapsible tube connecting the helmet to an air pump.

The actual diving dress is a combination suit from feet to neck, made of two layers of twill with fine rubber between, fitted at the neck with a vulcanised rubber collar having holes to which the screws of the breast plate are attached, giving a water-tight joint. Vulcanised rubber cuffs prevent ingress of water at wrists. The helmet is of copper with gun-metal valves. It is provided with glasses protected by a metal trellis work. Boots are provided with leaden outer soles and these, together with weights worn on the back and chest, serve to ensure equilibrium. The couplings of the helmet are made of gun metal.

The air pump is in general worked by hand, but in docks it may be driven by electricity or by steam. In such cases, the best system is to deliver the air not directly but into a reservoir to ensure reserve supply in case of a breakdown. Certain experts recommend the use of filters to ensure the air being free from dust, dirt, and oil. The air is delivered into the helmet and plays on the glass front in order to prevent condensation of breath on the glass. The diver can adjust the supply of air for different depths by regulating the air outlet valve so that his dress should be neither too much inflated nor, on the other hand, too tight — two extremely disagreeable conditions. An emergency cock is placed on the helmet in case the diver should inadvertently over-inflate his dress.

It must be remembered that the air pumps cannot deliver more than a fixed amount of air to the diver during a certain time. Should anything happen to modify suddenly the diver’s position (a fall, for example) the air pump will not respond to the new demand made and the diver may then find himself in a bad position. The diver may, however, be provided with a loud sounding telephonic apparatus (Siebe, Gorman, or Graham Davis apparatus) which permits of inter-communication between divers and their overhead attendants or other divers. For lighting purposes automatic self-contained hand lamps or even arc lamps with metal protectors are used.

A self-contained type of diving dress similar to the above may be used which permits of the diver carrying his own air supply, the apparatus having a knapsack...
with steel cylinder containing oxygen compressed to a pressure of 120 atmospheres and chambers of caustic soda and potash for restoring the exhaled air (see article "Breathing Apparatus"). This type of dress (see fig. 50) is suitable for work in shallow water.

Other types, on the contrary, allow the diver not only to attain great depth, but also to remain for a long time under water. There may be quoted here the "Fenzy" respiratory apparatus for deep-sea divers, which consists simply of a mask without diving dress, the "Leprieur" self-contained diving apparatus having also the Fenzy respiratory device, but rendered self-acting by being provided with bottles of oxygen or cartridges for regenerating oxygen; the "Kall-rose" apparatus, provided with 200 grm. of oxalythe for work at 7-8 metres and with certain slight modifications for work at greater depths; the metallic diving apparatus of the type Chester-Macdaffé, and especially the Neufeldt-Kuhnke (Kiel) apparatus (see figs. 51 and 52), weighing 250 kg. and allowing the diver to attain the great depth of 130-160 metres. A diver has succeeded in remaining under water for five hours at a depth of 160 metres with this apparatus.

According to W. Kucharski (of Kiel), this new "panzer" apparatus for deep-sea diving is said to offer the following advantages: liberty of movement and facility for working. While stay at the bottom is limited to one to one and a half hours approximately, by restriction to the number of bottles of oxygen carried, nothing will prevent the diver being provided with a greater number of bottles, thus augmenting his stay at the bottom to four or six hours, and even longer. A spell of work lasting three hours has already been effected. The length of stay made by the diver is of enormous advantage for the work carried out, since the descent and ascent are only the affair of a few minutes. Other advantages presented by this apparatus are chiefly concerned with the technique of work under water.

The additional pressure per square inch for each fathom of depth (salt water) may be calculated as follows:

<table>
<thead>
<tr>
<th>Fathoms (1 fathom = 1.62 metres)</th>
<th>Feet (1 ft. = approx. 30.48 cm.)</th>
<th>Pounds of pressure per square inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>9.7</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>5.3</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>8.0</td>
</tr>
<tr>
<td>4</td>
<td>24</td>
<td>10.7</td>
</tr>
<tr>
<td>5</td>
<td>30</td>
<td>13.4</td>
</tr>
<tr>
<td>6</td>
<td>36</td>
<td>16.0</td>
</tr>
<tr>
<td>7</td>
<td>42</td>
<td>18.7</td>
</tr>
<tr>
<td>8</td>
<td>48</td>
<td>21.4</td>
</tr>
<tr>
<td>9</td>
<td>54</td>
<td>24.1</td>
</tr>
<tr>
<td>10</td>
<td>60</td>
<td>26.7</td>
</tr>
<tr>
<td>15</td>
<td>90</td>
<td>40.1</td>
</tr>
<tr>
<td>20</td>
<td>120</td>
<td>53.3</td>
</tr>
<tr>
<td>25</td>
<td>150</td>
<td>66.9</td>
</tr>
<tr>
<td>30</td>
<td>180</td>
<td>80.2</td>
</tr>
<tr>
<td>35</td>
<td>210</td>
<td>93.6</td>
</tr>
<tr>
<td>40</td>
<td>240</td>
<td>107.2</td>
</tr>
<tr>
<td>45</td>
<td>270</td>
<td>120.3</td>
</tr>
<tr>
<td>50</td>
<td>300</td>
<td>133.6</td>
</tr>
</tbody>
</table>

**PATHOLOGY**

The disease caused by rapid decompression is, according to the opinion of many experts, greatly furthered in its development by unfavourable conditions, such as fatigue due to exhaustion in struggling with currents and being buffeted by waves and the effort to maintain an upright position. Rapidity of decompression greatly exceeds that to which caisson workers are as a rule subjected. Another factor is the length of immersion (shorter, however, than in the case of caisson workers), and a further cause may be the temperature of the water. Defective living conditions often serve to aggravate causes of ill-health, especially towards the end of the diving season. It must be remembered that divers are subjec-
ted to greater pressure than caisson workers, though for a shorter period, and that they are exposed when working in an upright position to a different sort of pressure in regard to the head and the feet. The head, in fact, has to support less pressure than the feet. If, for instance, the diver is 6 feet in height, there will be a pressure of about 3 lbs. less acting on his head than on his feet.

Leroy de Mercourt, of the French Navy, was the first to draw attention to the danger incurred by sponge fishers in pursuit of their occupation (1869). During descent divers are exposed to the same troubles as those referred to in connection with caisson work. Compression causes a rise in the body temperature due to the heat generated, and breathing often becomes painful after depths of 12 to 15 fathoms due to pressure of carbon dioxide in the helmet (see article "Compressed Air Work"). It is necessary to draw attention to the point already referred to in connection with caisson work. A large number of tests of the air contained in the diver's helmet have revealed that about 0.14 cu. ft. of carbon dioxide (measured at atmospheric pressure) are produced per minute when the diver is at rest and about 0.45 cu. ft. when he is working. The quantity of air required for the diver can easily be calculated:

<table>
<thead>
<tr>
<th>Depth in feet</th>
<th>30.48 cm</th>
<th>Air (in cu. ft.) at required atmospheric pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brasses (French fathoms)</td>
<td>(1 brasse = 5 ft. 3.77 in.)</td>
<td>Com. (1 cu. ft. = 28.317 c.c.)</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1.5</td>
</tr>
<tr>
<td>16</td>
<td>0</td>
<td>2.2</td>
</tr>
<tr>
<td>33</td>
<td>0</td>
<td>3.0</td>
</tr>
<tr>
<td>66</td>
<td>11</td>
<td>4.5</td>
</tr>
<tr>
<td>99</td>
<td>18</td>
<td>6.0</td>
</tr>
<tr>
<td>132</td>
<td>22</td>
<td>7.5</td>
</tr>
<tr>
<td>166</td>
<td>27</td>
<td>9.0</td>
</tr>
<tr>
<td>198</td>
<td>33</td>
<td>10.5</td>
</tr>
</tbody>
</table>

The excess of carbonic acid entails the danger of a larger amount of carbon dioxide than in normal conditions being pumped into the blood.

Let us suppose that, when just under water, the diver has sufficient air to prevent the CO₂ percentage in the helmet air from rising beyond 3 while he is at work. This will keep him fairly comfortable. If he now goes down 33 ft., the air supply being similar, the percentage of CO₂ in the helmet air will also remain the same. As, however, the pressure is now 2 atmospheres his normal alveolar CO₂ percentage will be 2.8 instead of 5.6. It will however be quite impossible to maintain this percentage of CO₂ in his alveoli since during work the percentage in the inspired air itself is 3. (Haldane)

The effect of CO₂ at a rate of 1 per cent. at 33 ft. is exactly the same as that at a rate of 2 per cent. at normal pressure or a rate of 0.5 per cent. at 99 ft. In other words, the effect of a slight CO₂ content in the helmet becomes greater as the depth at which the diver works is increased.

Under such conditions, divers suffer from violent panting, and discomfort increases with the depth if the air supply is not sufficient and provided the air in the helmet is not adequately renewed. The diver may experience discomfort at 40 to 45 metres. There is a sense of fullness in the head, buzzing in the ears, and flashes of light pass before the eyes, with bleeding at the nose, mouth, and ears. After quick ascent the men complain of intense pains throughout the body, especially the trunk. Derangement of sight and hearing, and tingling and itching in the limbs have been followed by loss of consciousness and paralysis—in fact, symptoms very similar to those described for caisson workers are experienced. Paralysis is typical of work done at great depth where, however, the work is only continued for a short period.

Sensory disturbances are mostly transitory and even paraplegia may disappear after an hour and a half. The itching and tingling sensation recurs rapidly, however, accompanied by paralysis which renders the worker powerless for long weeks. Thus, workers having once recovered easily become subject to relapses on resuming work.

An enquiry amongst sponge fishers has led one authority to the conclusion that disease forms produced by unduly rapid decompression may be grouped in the three following categories: (a) acute or lightning form with fatal termination; (b) acute or lightning form passing into chronic state accompanied by spasms; (c) mild form of short duration in the first place.

In (a) death may be immediate or, if life continues for a time, there is typical haematomyelitis with paralysis followed by death in a short time. In (b) the symptoms are succeeded by chronic spasms with loss of power and wasting. In (c) the symptoms are milder and pass away without after effects.

Cases of haematomyelitis due to rapid compression are fairly numerous. There may be mentioned the cases of Ellis (1891), Lepine (1899), Rho (1903), Cazamion (1912), Lantieri (1922: 3 cases,
DIVERS

— 586 —

2 of which were fatal), Boinet, Jean Pieri (1925: 2 cases, 1 of which was fatal), etc.

Statistical tables of cases of accident classified by age groups of the victims are as follows (according to Snell and Mazzolani):

### SNELL

<table>
<thead>
<tr>
<th>Age group</th>
<th>Number of divers</th>
<th>Accidents per 100 divers</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-20</td>
<td>55</td>
<td>—</td>
</tr>
<tr>
<td>20-25</td>
<td>145</td>
<td>10.3</td>
</tr>
<tr>
<td>25-30</td>
<td>362</td>
<td>23.3</td>
</tr>
<tr>
<td>30-35</td>
<td>68</td>
<td>36.3</td>
</tr>
<tr>
<td>35-40</td>
<td>3</td>
<td>166.0 1</td>
</tr>
</tbody>
</table>

1 An accident which occurred five times.

### MAZZOLANI

<table>
<thead>
<tr>
<th>Age group</th>
<th>Number of divers</th>
<th>Accidents per 100 divers</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-20</td>
<td>63</td>
<td>4.7</td>
</tr>
<tr>
<td>20-25</td>
<td>72</td>
<td>8.3</td>
</tr>
<tr>
<td>25-30</td>
<td>10</td>
<td>10.0</td>
</tr>
<tr>
<td>30-35</td>
<td>13</td>
<td>25.0</td>
</tr>
</tbody>
</table>

Forms of anaemia which are frequently met with amongst divers are rather difficult to explain since the accumulation of CO₂ in the helmet as well as oxygen pressure are without any special action on the diver's system.

Amongst possibly serious accidents should be recalled the bursting or faulty working of the air tube, loss of consciousness on the part of the diver engaged on submarine work, destruction of the air pipe or even of the diving dress caused by external agents (wrecks, sharks, etc.).

Zenos, of Athens, reported in 1904 a disease affecting sponge fishers without diving dress. The disease in question consisted in irritation of the skin of the whole body with itching, which developed a papular and pustular form of skin disease very difficult to cure and accompanied by fever. The lesion in question is due to contact with viscous and irritant substances secreted at the base or surface of the sponge by a living actinia.

### PROPHYLAXIS

The preventive measures of a general nature detailed in regard to caisson workers are applicable here (see article "Compressed Air Work"). Besides a very thorough medical examination on entering the occupation, the candidate should be subjected to preliminary tests consisting of a descent to a depth of 30 to 40 metres.

**Descent.** — The descent should, it is stated, be as rapid as possible, that is to say, as rapid as permitted by the air supply and by the effect of the air on the diver's ear drum. Each minute of descent represents wasted time since the blood is always becoming saturated with N. It is for this reason that certain authors are of opinion that it is not necessary to regulate the speed of descent. Other authorities, however, have suggested varying speeds — 0.50 metres per second, 1½ metres per minute, 0.50 metres per minute — to attain depths not exceeding 20 to 25 metres.

**Duration of immersion.** — There is seldom any question in diving of exposures of very long duration such as in the case of tunnel work; but as fatigue has proved to have a very strong influence in producing bad effects and contributing to the development of symptoms, it is advisable that immersions shall be neither too frequent nor too prolonged. For sponge fishers, however, it is often impossible to restrict to safe limits the time during which workers are under compression without encountering practical and economic obstacles. It is very important that sufficient time be allowed to elapse between successive immersions for complete desaturation prior to re-immersion. To ensure adequate precautions in this connection, workers should immerse in turns, larger relays being employed for greater depths. One expert demands for depths of 28 metres four relays, for depths of 40 metres six, and for depths exceeding 40 eight. Great care must be taken to limit as far as possible the length of exposure at considerable depths if bad effects are to be avoided. Haldane and Catsaras insist in their recommendations on these precautions being observed. For long exposures, where such cannot be avoided, correspondingly long periods of decompression are required (see later).

The diver must, therefore, not remain at the bottom longer than the time fixed, that is to say, for a shorter period than that necessary to cause saturation of the tissues with N. In the event of this precaution not being observed, the length of time required for desaturation will be so long that the period allowed for coming to the surface must of necessity be increased.

**Decompression.** — As in caisson work, the first method to be applied
was uniform decompression, many authorities advocating ascent at the same uniform rate as that of descent. Another authority demands three hours following an hour spent at a depth of 20 metres. Von Schroetter suggests 1.5 to 2 minutes per tenth of an atmosphere, but remarks that practical difficulties may be encountered in the application of this method (unduly long time spent in coming to the surface).

The method of stage decompression recommended by Haldane and Catsaras is particularly well suited to divers and has, to a great extent, replaced earlier methods.

Each diver knows that he can, without risk, ascend from a depth of from five to six fathoms \(^1\) (8 to 10 metres approximately) to the surface as rapidly as he likes. Where, however, he has been to a depth of 30 fathoms (48 metres approximately) he cannot do so without exposing himself to serious risk from the effects of compression. The reason therefor has already been explained in regard to compressed air work.

The fact that saturation of the tissues is slow is without doubt a very valuable advantage since by resting only a short time under the water the danger is greatly reduced. Greek divers, in fact, regain the surface from a depth of 30 fathoms almost as quickly as they wish, for they remain at the bottom a very short time (not more than ten minutes counting ascent and descent), and under these conditions the tissues have not time to become saturated.

During the ascent the diver must control his decompression, but it is nevertheless necessary that the length of time for each halt should be communicated to him since the diver has great difficulty in estimating the passage of time exactly. The diver can ascend without danger from 33 ft. to the surface, from 198 ft. (33 fathoms) he can ascend rapidly to 83 ft. (14 fathoms) or, in other words, from 7 to 31 atmospheres. If he is at a depth of 165 ft. (27 fathoms) or 6 atmospheres, he can ascend to 66 ft. (11 fathoms or 3 atmospheres) without risk, the proportion always remaining two to one. After this stage he must rest for a long time, and at each successive stage he must allow frequent intervening intervals to elapse to ensure the liberation of excess nitrogen. The duration of the halt succeeding the last feet separating him from the surface must be longer.

At each halt the diver should be encouraged to engage in muscular exercises, especially with those parts of the body which have been subjected to effort at the bottom. In this manner, circulation is accelerated, and desaturation of the blood in the most completely saturated tissues is increased.

It is also advisable to diminish at this point the quantity of air sent through the supply pump with a view to increasing slightly the carbonic acid content of the air in the helmet. In this way, volume and frequency of respiratory exchange is increased and this also favours elimination of the nitrogen.

For divers in northern latitudes and particularly in winter this stage method, which diminishes the length of decompression, offers signal advantage, since lengthy ascent to the surface is very trying. In certain cases it is necessary and often essential to accelerate the ascent by limiting the duration spent at the bottom and reducing decompression time. Even at a depth of 47 metres a diver should not be allowed to remain longer than twenty minutes. He should thereafter ascend rapidly to 15 metres where he must remain two minutes. He then ascends 3 metres further and rests again for three minutes. At 9 metres he makes a halt of five minutes and at 6 metres of eight minutes and finally of ten minutes at 3 metres. The total duration for decompression thus amounts to thirty-one minutes which can be easily endured.

It has been stated that it is preferable for the diver to ascend by the aid of a ladder than to be pulled up to the surface on giving the signal, since the exercise involved favours elimination of nitrogen. The fact that amongst naval divers cases of illness are rare proves the value of the system when enforced with the necessary discipline. The proof of the contrary is founded unhappily on the numerous cases of illness met with amongst pearl divers and sponge fishers who lack the same discipline and rigorous supervision. In the navy a manometer indicating the depth at which the diver is working is attached to the air supply pump, with further control by means of gradations inscribed on the air pipe. An attendant in the diving boat records time and depth, and signals to the diver to ascend and halt in accordance with prepared tables provided for the purpose. Thousands of descents to depths of over 33 metres with decompression on the lines of Haldane's methods were affected with but 2 cases of illness, and these latter due to unavoidable infringement of the regulations, that is to say, to natural inevitable causes (a storm and entanglement in a wreck).

Hill had a diver's bell or caisson for divers constructed in such a way that

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\(^1\) French fathom of brasse = 5 ft. 3.77 in.
the diver could enter it under water and remain at the maximum pressure experienced until withdrawn from the water and put into a decompression lock. Progressive decompression can also be applied with this apparatus. Its use, however, is only possible in harbours and it is not practicable for isolated workers such as sponge fishers, etc. There has also been studied and applied practically a special apparatus allowing the diver to rest under water (submarine sleeping room, "Siebe" model, "Gorman" model).

Researches effected recently (1926) in the United States by the Admiralty, the Public Health Service, and the Bureau of Mines have given promise of the use and practical application of a type of synthetic helium atmosphere to be used for during the whole time of compression for the full length of time spent under compressed air.

Since all authorities agree in recognising the nitrogen content of the air as constituting the principal factor in the formation of gas emboli in the vessels at the moment of decompression, the question arises as to whether it would not be possible to replace this gas by helium.

Animal experiments in relation to the effects of this gas have demonstrated that, coupled with a reduction in the quantity of oxygen to a content below the normal, it would be possible to create an artificial atmosphere much less injurious to divers than ordinary air. Decompression time could be reduced from a third to a quarter, and the injurious effects of oxygen poisoning eliminated.

Helium offers the advantage of being 50 per cent. more soluble than nitrogen, which has the effect of reducing greatly the quantity of gas in excess which the human organism can store during the period of decompression. Further, the molecule of helium being smaller than that of nitrogen this gas diffuses more rapidly, thus facilitating its liberation when it is present in excess in the tissues.

Were it not for the high cost of helium the possibility of using a synthetic atmosphere composed of helium and oxygen at a depth not exceeding 70 metres, and this would permit of the salvage of many wrecked ships at present considered as irretrievably lost in consequence of the enormous length of exposure and length of decompression involved.

It should be mentioned that this type of air has been utilised with great success in experiments made on divers in the United States.

For man the normal atmosphere may be replaced by an artificial atmosphere containing 1.5 to 15 per cent. of oxygen and 92.5 to 85 per cent. of helium according to the pressure, up to 10 atmospheres, a pressure which has not so far been exceeded by man but which might be borne by him during five hours. On the other hand, tests at present in progress (1928) in regard to human beings lead to the expectation that it will be possible to use helium in masks allowing of recuperation of this gas, the whole body except the nose and mouth being plunged into an atmosphere of nitrogen and oxygen less rich in oxygen than the normal atmosphere. These tests have been specially instituted with a view to establishing decompression tables sufficiently reliable to eliminate the risk of accident.

First Aid

Recompression for divers is usually effected by daily reimmersion during a short time on each occasion and carried out for a more or less extended number of days. Decompression following recompression must be very cautiously applied: at least one hour per atmosphere or even longer according to the state of the patient. Pressure should be immediately raised on signs of relapse and decompression continued at a slower rate, for prolonged decompression of this description can, of course, only be applied where an air lock is available. Otherwise, divers suffering from compression or illness are advised to become immersed thrice daily for two or three months at depths of 15 to 20 metres, remaining fifteen to thirty minutes at maximum pressure and then undergoing decompression by stages or, better still, "broken" decompression (Glibert's method) which tends to eliminate the risk of effervescence. Where a lock is not available, reimmersion with slow decompression aided by oxygen inhalation is advisable. An exhausted diver should be brought rapidly on the surface and placed in a decompression lock where such is available.

Whenever possible, a medical lock or diver's bell should be set aside for de-
A portable recompression chamber should be erected on the diving boat when dangerous operations are in progress. Suggested dimensions for this chamber are 1.50 by 2.30 metres, providing room for the patient and attendant. There should be a well-facility for removing the diver's equipment and giving him the necessary attention.

Certain authorities hold that oxygen under pressure offers great advantage during decompression and allows of reduction of decompression time to a minimum. It has been suggested that oxygen should be distributed from warships to small divers' boats and that divers should inhale it for ten to fifteen minutes after coming to the surface. This recommendation is embodied in a Greek Act, while German regulations enforce the use of oxygen in the manner just described, and it is said that the adoption is to the effect that a supply of oxygen should be available whenever the diver emerges from a depth of over 20 metres in a period of time shorter than the standard time (1.5 minutes per tenth of an atmosphere) or, in fact, after each over-dive and decompression. Oxygen should be administered to the diver before he takes off his helmet, by means of the air supply tubes or supplementary sidepiece of the helmet, and oxygen inhalation proceeded with during unfastening of the diver's garb. This arrangement also represents an advantage, owing to the complexity of supplying the requisite mixture, 40 per cent. of oxygen and to be altered in proportion to reduction of the absolute pressure and to the speed of ascent. Owing to the necessity for these, the use of a neutral gas, such as hydrogen or methane, mixed with oxygen for depths of 50 metres, the mixture to contain 30 per cent. of oxygen and to be altered in proportion to reduction of the absolute pressure and to the speed of ascent. Owing to the complexity of supplying the requisite mixture, 40 per cent. of oxygen, 60 per cent. of hydrogen at 30 metres, and 80 per cent. of oxygen, 20 per cent. hydrogen at 20 metres, etc., it is preferable to provide divers with a decompression apparatus which they can regulate than to have the mixture supplied to them by a pump from above.

This arrangement also represents an economy in the amount of oxygen required. The diver gets two steel flasks, one containing 100-200 atmospheres of compressed oxygen and the other hydrogen at the same pressure. Each has a stopcock which permits of a definite percentage of each gas being emitted. The oxygen pressure must at first be low and must only reach 100 per cent. during the ascent, while the hydrogen pressure must, on the other hand, gradually decrease. It is, however, impractical to leave the manipulation of this apparatus to the diver himself. Automatic self-regulating valves should be used, giving the desired pressure at appropriate depths (see article "Breathing Apparatus"). For provision of a caustic soda chamber required to purify the air passing through the helmet, see article "Breathing Apparatus".

If the diver, on coming to the surface, is found to be unconscious, artificial respiration should be applied immediately and continued till breathing becomes normal. If he has collapsed, warmth should be applied to the extremities and, if he cannot breathe, oxygen should be administered. As soon as he revives he should be removed to hospital and kept under medical supervision.

It has been recommended that fishing grounds should be visited by two or three Government warships to enforce adequate regulations and that hospitals situated on the beach should be opened for treatment of sick divers and should be provided with two or three diving installations for recompression treatment, as well as apparatus for the production of oxygen.

The following list of general precautions has been drawn up for divers:

1. Never exceed 60 metres depth (on an average not below about 52 metres).
2. Regulate stay under water as follows:
   - 15-30 metres: 1 hr.
   - 30-50: 20 min.
   - 40-60: 10 min.
   - 50-60: 5 min.
3. Decompress slowly.
4. Avoid as far as possible successive immersions. Divers should strip after immersion before undergoing a second immersion in turn with his companions.
5. The diver should not be obliged to walk far or to struggle against the waves.

Sunday should be observed as a day of rest for divers during the sponge-fishing season. Sponge fishers should have at least fifteen days' rest and should be well nourished to counteract the effects of malnutrition and over-exertion during the season.

**LEGISLATION**

See also article "Compressed Air Work". Measures in regard to the work of divers have been issued by the mercantile and
naval departments in all countries. A Legislative Code for sponge fisheries exists in Greece and Italy. The Greek Act No. 3617 of 10-25 March 1910, relative to sponge fishing, divided on by divers, makes provision for a divers' school through which all candidates who must be at least twenty years of age must pass before qualifying as divers or captains or foremen of diving boats. All candidates suffering from heart or lung affections, chronic ear or nose trouble, advanced neurasthenia, paralysis, or given to alcoholic intoxication are excluded from the occupation.

After completing the course the divers receive a certificate of efficiency, and the captains and foremen a diploma.

Very detailed measures have been drawn up in regard to sponge fishing. The captain is obliged to call in immediately the nearest doctor to treat any diver who has been the victim of an accident in the course of his work.

The captain must notify immediately any case of death or illness occurring amongst the divers to the commander of the warship inspecting the fishing operations or to the consular authority at the nearest port.

This Act also provides pensions for divers (sections 28 and 29).

The Order giving effect to this Act is dated 25 February-9 March 1912. It prescribes amongst other things, that the captains must provide nourishing food of good quality for the divers, in accordance with the provisions of the Admiralty Order.

All divers suffering from cold or having digestive, skin, or other organic affections must be withdrawn from work until completely cured, and all workers having partaken of a full meal or in a state of intoxication must be refused permission to dive.

The duration of the stay under water at various depths shall be as follows:

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.5 - 27.70</td>
<td>1 hr. (max.)</td>
</tr>
<tr>
<td>27.7 - 37.00</td>
<td>30 min.</td>
</tr>
<tr>
<td>37.0 - 46.75</td>
<td>15</td>
</tr>
<tr>
<td>46.75 - 55.50</td>
<td>10</td>
</tr>
<tr>
<td>55.5 - 64.75</td>
<td>5</td>
</tr>
<tr>
<td>64.75 - 74.00</td>
<td>3</td>
</tr>
</tbody>
</table>

It is strictly prohibited to keep a diver longer than the time stated above at these depths. Those in charge of diving boats must see that divers do not endure undue strain and fatigue and do not have to struggle against currents.

Divers must not be drawn up rapidly to the surface or must not themselves come up rapidly, filling the diving dress with air. The ascent must be made at the prescribed rate: 1.85 metres per period of thirty seconds with a halt of one minute at each 3.70 metres.

It is strictly prohibited to make consecutive dives without intervals. Sunday must be regarded as a day of rest. Fifteen days' leave at least must be granted to divers who have been employed without interruption for two months.

Immediately the first symptoms of divers' disease appear, the victim must put on his diving dress and redescend to 19-23 metres, remain at this level for from fifteen to twenty minutes, and then come up very slowly. Each diving boat must carry reserve diving apparatus for each diver in case of sickness, reimmersion should be necessary. Each boat must carry at least two steel cylinders of oxygen to be administered as soon as symptoms are manifested.

**Italy.** — The Government Order of 4 June 1913 sets forth rules and practical recommendations in regard to the occupation of diving (sponge fishing and the requisite stay under water).

Section 1 enumerates all the details of safety and hygiene relative to precautions preparatory to diving, and section 2 those relative to the descent. The Order sets forth that the descent may not be excessively slow, in order to avoid increasing unduly the stay under water. A good diver may descend at a speed of 20 metres per minute and even more rapidly as depth increases. Section 3 includes minute instructions to divers while at the bottom. The diver, when obliged to lean over and bend, should allow air to escape from his suit by the outlet valve. If he has to work with his body bent forward and his head bent, the pressure of water on his back (being higher) is lower than that acting on the air valve placed lower down. It may then happen that the air, before having attained at the entrance to the valve the requisite pressure for penetrating, being subjected to the external pressure, accumulates in the upper parts of the dress and inflates it to such an extent that the diver is raised and caused to ascend rapidly to the surface. In these circumstances, the diver can obviate the grave risk of a rapid ascent by keeping the valve open so that the air may not escape while his head is in a position inferior to the other parts of his body.

Section 4 is devoted to possible accidents at the bottom during divers' work (in-disposition, heaviness of the limbs, inflating of the diving dress, compression of the air tube, loss of a boot, twisting of the rope or of the air tube, etc.).

The supply of air to the diving dress is dealt with in section 5 and the return to the surface in section 6. The latter contains a table A (see page 591) regarding the stay permissible at different depths as well as the intervals to be allowed during the descent. The rate of ascension is regulated somewhat as follows: from the bottom up to 10 metres from the first halt at a rate of 1 metre per three seconds or a speed corresponding to about 20 cm. per second. For the last 10 metres before the first halt there is prescribed a rate of six seconds per metre, corresponding to two seconds per 30 cm. This latter rate should also be observed between each subsequent halt.
Table B deals exclusively with cases in which, owing to force of circumstances, the stay at the bottom is of necessity rendered longer than provided for in ordinary circumstances dealt with in Table A. These tables are fairly similar to those issued by the British Admiralty. The two final sections 7 and 8 are devoted to first-aid treatment to be given to divers in the case of accidents as well as the methods to be followed for artificial respiration.

As a result of the Report of the Committee on Deep-Sea Diving addressed to the Admiralty in 1907, there was issued in Great Britain a whole series of measures dealing with divers' work, which were amended in 1916 and 1924. The majority of these provisions are the same as those already above referred to for the Italian Navy, the times fixed for the stay at the bottom and the ascent being fairly similar.

Egypt. — Decree of 21 April 1926 relating to sponge fishing. A law relating to pearl fishing was issued by Venezuela on 29 May 1926.
DOCK 'LABOURERS

At the 1910 meeting of the International Association for Labour Legislation, the Committee entrusted with the study of work in compressed air adopted the following guiding resolution:

"Since divers, especially those attached to salvage warships, may be called upon to work in foreign waters or even have to embark on warships belonging to a nationality other than their own, it would appear desirable to provide an international code of regulations for their protection."

Compensation and notification of cases of sickness amongst divers are subjected to the same legislative provisions as those provided for work in compressed air. For Bibliography, see article "Compressed Air Work".

Dock Labourers


GENERAL REMARKS

The work of dock labourers comprises all the operations necessary for the loading or unloading of ships, the transport of goods to the docks, the conveyance to warehouses and to trucks, as well as all such associated manipulations as measuring, weighing, repairing and packing. In spite of rationalisation, adopted by some firms, and the ever-growing use of machinery, such as lifts, cranes, grain elevators and moving conveyers, certain operations are still necessarily effected by hand.

Dock work does not, as a rule, require special training or aptitude, beyond physical strength and muscular resistance. But the work is characterised not only by bustle and hurry — economic competition making it essential that the various operations shall be executed as rapidly as possible — but by considerable irregularity, depending upon the arrival of cargo ships. Further, the supply of manual labour is strongly affected by recruitment from a floating population coming chiefly from the country.

The phases of work vary according to the nature of the goods, and the treatment they require.

Moreover, stowage necessitates special skill and labour in order to ensure the stability of the goods in the holds of the ships, and to place them in such a manner that unloading at successive ports is facilitated.

General goods, such as cast-iron, iron, sheet-iron, articles made of iron, copper, tin or zinc; as well as such loose cargoes as refractory stones, chemical products, minerals or coal, are generally hoisted by means of various apparatus, like slings, chains fitted with hooks or jaws or grabs, trucks, trays, nets of string or wire, or ordinary or automatic hods. Except in the case of automatic hods, the workmen have to load the various receptacles with a shovel, which is a decidedly disagreeable and troublesome operation, especially in the case of very dusty minerals. A mineral at times may become so welded together that before it can be handled it has to be loosened with a pick or crowbar; while other minerals may arrive at the port still in a heated state, e.g. at Antwerp a cargo of minerals is said to have arrived so hot that it reached 100° C., according to the workmen's report.

It is not possible to quote in detail all the operations involved in dock work, in the transport of hides, and in unloading luggage from on board merchant ships; but there must be borne in mind the way in which the loads are carried, either held by one or both hands, or with the fingers, or carried on or against such different parts of the body as the head, the back, the shoulder, sometimes the thoracic lateral surfaces, or the abdomen while sometimes they are suspended. The method adopted varies with the weight, shape, volume, and available space, with the habits of the workers, and also according to whether the load has to be moved in a vertical direction, say, from the hold to the deck of the ship, or from the quayside or from the lighters to the hatchways of the boats, or horizontally from the ship to the quayside and vice versa. Horizontal or oblique are the most usual directions. Men, when unloading, scarcely ever carry loads on the head; they generally carry things like small packing cases, baskets, or bricks in their arms when they only have to go a few steps; when they are stationary, they are usually carried in a chain, the packages are passed from hand to hand. A much more common way of carrying loads is on the shoulders or on the back, using the arms stretched upwards, thus increasing the breadth of the shoulders, and steadying the load; or else it may be carried supported on the loins or against the hips in order to lessen the strain on the dorsal and lumbar muscles. (See also article "Transport ").

These various manipulations are generally carried out by adults grouped in gangs under the supervision of a foreman. In Europe women do not, as a rule, carry heavy work in docks, but they often help in some operations, like opening, mending, piling up empty sacks, shortening up grain of maize or rice which has run out of sacks that have been torn, or beating and brushing salted hides.

SOURCES OF INJURIES

Medical literature rarely deals with dock labourers, although the sanitary and hygienic conditions of their work

Despite the risks and working conditions, the injuries sustained by dock workers include:

- Torn or torn clothes
- burns
- injuries to the hands and fingers
- injuries to the knees and ankles
- injuries to the back and spinal column
- injuries to the shoulder and arm muscles
- injuries to the head
- injuries to the eyes
- injuries to the ears
- injuries to the lungs
- injuries to the stomach
- injuries to the liver
- injuries to the spleen

It has been estimated that the rate of injuries among dock workers is higher than among other workers due to the nature of their work and the environment they work in.

In conclusion, the working conditions of dock labourers, although improved over time, still present challenges for the health and safety of workers, and require ongoing efforts to ensure their well-being and protect them from injuries.
leave much to be desired. The risks for these labourers may be summarised as follows:

Heavy Work

The work of dock labourers is hard, exhausting, and requires strenuous effort, often involving strained attitudes, and difficult conditions of work.

The physical effort required is chiefly a function of the weight of the loads carried, which varies considerably, sometimes amounting to 30 kg. for loads of wood at Antwerp, or to 38-40 kg. for clusters of bananas in ports of the United States; or to 70 kg. for bags of coffee in the United States.

The loads most commonly occurring vary between 85-100 kg. at Antwerp; sometimes, but not often, they approach 120 kg. at Marseilles and Cardiff; and he has to stoop down and bend his neck and back forward or sideways, and to stiffen the muscles of the thorax and the counteracting abdominal muscles, in order to stem the forward thrust imposed on the body by the load. The extensor muscles of the lower limbs are also held contracted so as to prevent them from giving way under the pressure of the loads.

In some cases weights are carted in wheelbarrows or small trucks, or they may be rolled in barrels and casks.

The distance to be covered must also be taken into account, and the inclines the men have to go up and down, as well as the nature of the ground; and also the hours of work, which at night or by day are generally eight hours, with certain modifications which may extend the period to nine or ten hours.

sometime, but even less often, they are heavier than this at Dunkirk. Sugar from Cuba is put up in sacks weighing 150-170 kg., and even weighing from 96 to 240 kg. according to the statistics of the Stevedores' Sickness Insurance Society of Moscow for 1926.

Carrying on the shoulders is hard work, and can only be done by robust men who are trained to it, and what makes it harder is that the man who carries the load often has to make the effort of hoisting it on to his shoulders, and lowering it, unaided or nearly so. From the physiological point of view, maintaining the centre of gravity involves extra effort; a man carrying a load walks with his legs apart, thus widening the lower part of the body, or

The time for rest in between is generally insufficient for restoring the strength, as the rhythm of the work is hurried, with rapid coming and going.

Transport work on scaffoldings and sometimes on insecure erections of course increases the risk.

Apart from these kinds of heavy work there is other work which is confined to manipulating apparatus used for hoisting or unloading; it is characterised by monotony, but demands concentrated attention, hence it causes nervous or psychic exhaustion.

A crane-driver's work, in particular, necessitates constant attention of eye and mind, as well as co-ordination between the muscles and the brain, always on the watch, to follow the
hooks and cradles, and place the crane in the best position for loading and unloading. The crane-driver is often helped by a labourer standing on the quayside or on the ship's deck, who indicates by signals the operations to be carried out. But if this man is not efficient, if he gives signals which cannot be clearly seen or which are somewhat ambiguous, instead of helping the crane-driver he may make the work more difficult and exacting. Watching for unforeseen vibrations of the crane, due to the excess in, or bad distribution of, the loads which may imperil the crane's safety, is also a cause of fatigue.

The crane-driver works all alone in a little cabin, perched 10-13 metres above the ground, in which he has to stay for many hours on end almost motionless, standing most of the time, working nearly exclusively with the trunk of his body and his arms, often insufficiently protected against winter cold or summer heat. The mental strain of his work, the continuous sense of great responsibility, as well as the physical fatigue and the isolated conditions, are all factors which bring in their train serious strain and psychic exhaustion.

### Harmful Products

Irritating and poisonous dusts hold the first place among harmful products. They arise from all kinds of materials transported in the raw state, or as prepared products, from grain, minerals, coal and some chemical products. The amount of dust rising from grain varies according to the kind, the presence of associated impurities, the place of origin and the methods of unloading. This type of dust generally consists of sharp spikes like hairs and small pieces of vegetable matter, with spores and mineral particles, which, according to Middleton, generally form a very small part (5 per cent.) of the total number of particles. The hairs are generally thick, strong and sharp, so that they can penetrate into the mucosa of the upper air passages. The differences in form account for the different pathological troubles encountered. Thus it is found that the rather long spikes from corn cause direct symptoms of respiratory irritation. According to the testimony of the dockers themselves, this dust seems to be the most irritating, even when the grain is clean and healthy. Barley produces a large proportion of very fine hairs which penetrate to a considerable depth into the respiratory passages.

These particles do not cause immediate symptoms of irritation; but before long an irritative bronchitis sets in. Maize cargoes, on the other hand, according to Middleton, do not seem to cause harmful dust. Middleton held an enquiry in 1924, and out of 43 dust counts made with Owens' dust counter, 24 were found to contain from 190 to 3,880 hairs per 500 c.c. of air, with an average of 932. The most usual figure was 1,658 hairs in wheat dust and 1,147 in barley dust. At Antwerp it is said that grain from the Black Sea is the most dusty; then, in descending scale, come Egyptian barley, corn from India in sacks, North American grain sent loose, and Argentine grain. Elevators fitted with hoppers cause most dust; next comes unloading loose grain with baskets. Operations connected with weighing machines, especially if they are of the old-fashioned type, worked by hand, expose the men to the inhalations of large quantities of dust. Moreover, the dust increases each time the grain is handled, due to the grain rubbing against each other. Damage caused by dust from grain is often due to the parasites which it may contain (acarisis).

The most dusty minerals are roasted minerals, which in some cases are sprinkled with water before being unloaded. The risks depend, of course, on the poisonous substances which these minerals contain, such as lead, manganese or arsenic; but they also depend on the quantitative and qualitative content in silica. Some manganese minerals from India may contain from 12 to 15 per cent of silica, and the dockers of Antwerp look on this mineral as the dustiest and most dangerous, together with calamine from Malfidane, which may sometimes contain a high percentage of lime. There should also be mentioned coal dust, dust from cement, basic slag and glass. New Zealand dockers recently (1927) complained of basic slag dust, and also of dust from guano coming from Walpole Island. Packing materials do not always provide an adequate protection, for they are often corroded by the chemical products which they contain.

Irritant liquids are sometimes looked upon as dangerous when tank-ships containing mineral oils are being loaded or unloaded, although these operations are generally carried out automatically. Poisoning may be caused by fumes liberated from these products (Riceel).

Poisonous gases may accumulate in the holds of ships: carbon dioxide, phosphoretted hydrogen from cargoes of ferrosilicon, and hydrocyanic acid.
and sulphur anhydride, after clearing ships of rats (see later). Rothfuchs reports that in 1926-1927, two fatal cases of poisoning by hydrocyanic acid occurred among ship inspectors (Schauerlaub).

Animal Products

The handling of animal products, such as hides, skins and wool, or of rags may expose the dockers to the risk of infection, and, in particular, to anthrax. Workers on board ships coming from ports infected with plague or cholera may come in contact with goods infected with insects that are carriers of pathogenic micro-organisms, or containing traces of excreta from persons stricken with infectious disease (Peri).

Accidents

A serious occupational risk is constituted by the numerous accidents arising while at work. These accidents are caused either by difficulty in handling the various goods or by the environmental conditions under which the work is carried on, the workers being obliged to move about in a quick orderly manner, in spaces which are often ill-lit, very restricted, blocked up with various objects, with machinery in action, on an uneven or unsteady surface, nearly always on a steep slope, and, high up above the quayside and the water, on ladders and gangways.

Accidents are also caused by falling loads, or working tools such as hooks and shovels, which are generally heavy and cumbersome.

Statistics

As a rule there is no age limitation for dock work, which is carried out by workers between the ages of seventeen and sixty or seventy years; but statistics drawn up

![Coal raised from the hold, ready to be discharged.](image)
Levi-Bianchini drew attention to a pseudo-oedema of the shoulder among dockers who unload coal.

The faulty construction of the handles of trollies and tilting trucks may cause blisters, callus and abrasions on the hands and fingers, even when gloves are worn; and even the wearing of protective pads, weighing from 3 to 4 or even 8 kg. (Moscow), fixed between the shoulder-blades, and reaching down to the lumbar region, may cause skin lesions on the back, especially in summer.

Unloading iron ore has caused cases of septicemia, the way being prepared by wounds on the hands (Riedel).

Dermatitis due to dust, to liquids, or to irritant or caustic products is aggravated by perspiration, generally intense in degree during work. In the case of workmen unloading grain these troubles are often caused by parasites (pediculosis ventricosus) in the grain (see article "Silos"). At Trieste, Freund, in 1926, observed a case of toxic bullous lichenoid melanodermatitis, originally described by Hoffmann, caused by the handling of tar. Coustan has observed cases of inflammation of the ear, followed by otorrhea, among men whose work is to unload coal and especially briquettes. Work with sulphur and pyrites from Cyprus has caused pruritis and ulcers on the skin (Riedel), and also blepharitis and conjunctivitis, such as Layet has also observed among unloaders of guano.

Chronic troubles of the cardiovascular system, that seldom become acute, see articles "Strain" and "Transport".

Among respiratory troubles should be mentioned colds, bronchial catarrh, and pneumonia from dust and bad weather. Unloading ores of copper and magnesia has sometimes caused spitting of blood and nose bleeding; basic slag is a well-known cause of pulmonary affections, which are often fatal. A case of secondary penicillosis of the lungs in a workman who had been unloading coal, has been described by Pezzali (1921).

The handling of manganese ores has been known to cause malaise and vomiting (Riedel).

Some casualties are perhaps of anaphylactic origin; among these may be classed the feverish reaction of short duration which, especially in the evening, affects a large number of workmen occupied in unloading grain. A person, who is not used to it, on going down into the hold of a ship where grain is being unloaded, immediately experiences irritation of the upper respiratory tracts, with sneezing, cough, and a burning sensation, as if he had caught an ordinary cold; this lasts all the time he is in the dust-laden atmosphere, and even persists after he gets back into the fresh air, sometimes for several hours. Different individuals are affected in different ways; sometimes a slight immunity is established or at least a diminution in susceptibility (Middleton).

Pulmonary tuberculosis is found among dock workers in a comparatively high percentage, aggravated, some experts say, by inhalation of dust followed by pneumonoconiosis, too much work, exposure to factors that induce colds, and abuse of alcohol.

Various digestive troubles seem to be due to fatigue, to muscular efforts which result in visceral displacements, to the irregular meals, to anti-hygienic habits in choice of food and to the abuse of drinks, especially alcoholic drinks.

Crane-drivers show a high rate of morbidity from nervous troubles. When they come down from the cabin they often experience a subjective sensation of want of balance, of instability of the legs, impediment of speech and difficulty in finding words (Tedeschi). But these troubles generally disappear rapidly.

Tedeschi in 1908 described how among the drivers of hydraulic cranes in the port of Genoa he found an occupational neurasthenia especially characterised by anxiety neurosis, a condition described by Freund, or a neurosis of waiting, described by Kraepelin, with cephalitis, a painful sensation of constriction of the neorasthenic helmet — first in one part, then in another. He also observed giddiness generally subjective, but sometimes revealed by objective manifestations — the phenomenon of Romberg.

This condition of anxiety, which sometimes amounts to a phobia, may disappear after a few minutes, or come on again and last for sometime after work is over. The patient is haunted with the fear of not working his crane correctly, which makes the risk of accidents greater. Some cause arouses the anxiety syndrome for the first time, after which it may recur, with a tendency to persist, for less and less reason, or even for no reason at all.

Tedeschi has also observed nystagmus, due to strain of the ocular muscles, combined with the strain necessary for watching loading and unloading operations. This form of nystagmus is noticeable when the patient looks sideways. It was found in 20 per cent. of the
workers, generally unknown to themselves.

Among infectious diseases the most important are anthrax from unloading skins, and certain epidemic diseases, such as yellow fever at St. Nazaire in 1864 (Layet), and cholera and plague at Naples. The first cases of these epidemics in Europe and America have occurred among dockers. Besides the causes directly connected with their work, these workers, by the actual conditions of their life, are exposed to other sources of infection, e.g. from drinking contaminated water; and, as a matter of fact, they are responsible for a large percentage of local outbreaks of typhoid and dysentery (Heijermans).

Fig. 56. — Discharging iron ore.

The tiring life these men live and their exposure to all weathers, explains, according to some experts, notably Gobiewsky, why they consume so much alcohol. There are also many cases of venereal diseases among them. The mechanical action of the burdens may aggravate at the points of contact, the formation of gummata in the case of syphilitic subjects (Peri).

Speaking generally, from a social point of view, the occupation has serious disadvantages; continuous exercise of strength tends to encourage violence; mental inertia characterises the execution of the work: long hours of idleness give opportunities for drink-
periods of work carried out by shifts (Riedel).

In the case of noxious gases the ordinary measures of precaution must be taken, with ventilation of the holds, roping together of the workers, and preliminary inspection of the ship (see later).

In the case of microbial agents, it must be admitted that the use of disinfectants does not always give real protection, and it is important to dress immediately any injury or wound that might offer an entrance to germs.

As regards preventive measures to be adopted as a protection against venereal diseases, see article "Seamen".

A number of injuries might be avoided if harmful substances could be packed in cases, sacks or barrels, with labels pasted on, the same label being repeated on the consignment papers accompanying the goods being dispatched (Riedel), in order to attract the attention of the workers whose job it may be to handle them.

As a protection against other sources of injury, especially bad weather, the general rules for personal hygiene apply; and as a protection against accidents the necessary safety precautions must be adopted.

In erecting temporary scaffolding and inclines, the loads to be carried must be borne in mind. Lighting, especially for work in the holds, must be adequate, and electricity should be used if possible, as other means of lighting foul the atmosphere by combustion gases, and may cause fires.

The organisation of first-aid arrangements is of great importance; it must include first-aid and dressing boxes containing the necessary material; rapid transport for wounded or sick by stretchers and ambulances; and conspicuous notices indicating the spot where the first-aid boxes and means of transport may be found.

At Hamburg, for example, all the docks have first-aid stations under the direction of a doctor, who also makes a point of being on the scene of work at fixed hours. These stations have a trained staff in attendance night and day, who give first aid, and have at their disposal ambulances for rapid transit to hospital. In these docks the ships make use of special signals for calling up police boats or custom-house officers patrolling the harbour. Special boats have been provided for the transport of injured workers (Rothfuchs).

Organisation for bodily cleanliness after work is extremely important; douche baths and cloak-rooms make for individual hygiene, which might at least save a good deal of illness. The development and improvement of rest-rooms and popular kitchens are also desirable.

Drinking water or such non-alcoholic drinks as coffee or tea should be at the disposal of the workers; the signing-on places should be suitable for their purpose, so that the worker is not obliged to wait for long hours in bad weather; improvement is needed in the

Fig. 57. — Moving coal baskets. Walking up a plank oscillating under the feet.
DOCK LABOURERS

means of transport provided for the personnel, especially within the docks.

These measures should be satisfactorily supplemented by an examination of the workers at the time of engagement, so that men who are not suitable for dock work on account of their mental and physical constitution or the functioning of the organs of the body, may be eliminated. This refers especially to workers put in charge of hoisting apparatus. Propaganda must be intensified among the personnel interested, in order to overcome the characteristic indifference and carelessness of this section of the working class as regards hygienic measures (Heijermans). They do not always do their part in improving the sanitary conditions of their work (Riedel).

It may be helpful to devote a few lines to the problem of the fumigation of ships, which is carried out in some docks under the supervision of a medical inspector. There are two possible methods of fumigation: one with sulphurous anhydride, and the other with hydrocyanic acid, which is liberated by means of special apparatus (Clayton, Marot, Vasaco, etc.). In some countries there is preferred sulphurous anhydride or a mixture of sulphurous-sulphuric anhydride, which is generated by the Clayton apparatus. Sulphurous anhydride seems to have a more intense power of diffusion; and it does not cause any serious risk to man.

But hydrocyanic acid is lighter than air, and does not diffuse so well as sulphurous anhydride; and there are serious risks in the use of it, as has been seen from the numerous accidents that have occurred of recent years (Colombani).

In a memorandum issued by the British Ministry of Health on the fumigation of ships with cyanide of hydrogen, great stress is laid on the danger of the process "which must only be carried on by responsible people possessing a sound knowledge of the nature of the gases and of the necessary precautions". This memorandum also gives detailed information as to the nature of the gas, its production, the precautions to be observed, the rules to follow in opening up again and in regard to ventilation, what has to be done with the residues, the use of gas masks, the symptoms of gassing and the treatment of patients.

For some time past attention has been given to simplification of the production of hydrocyanic acid, and to securing greater safety by using warning gases which are quickly perceptible to the smell, or which have lachrymatory properties. A German product known as "Zyklon-B", an earthy substance impregnated with hydrocyanic acid and chloropicrine, possessing lachrymatory properties, enjoys a pronounced preference in the United States, where the use of this product, combined with safety measures depending upon a chemical test which makes it possible to determine the presence of hydrocyanic gas after airing has taken

![FIG. 58. — Embarking luggage by means of a conveyer.](image-url)
place, seems at the present time to constitute the most advanced method for the fumigation of ships (Clark).

In Italy sulphurous anhydride has been and still is the most commonly used gas for fumigation on a large scale. Hydrocyanic gas has also been used since the latter years of the war, with chloropicrine and phosgene. Of the three, hydrocyanic gas seems to be firmly established. The reason why a substitute for sulphurous gas has been sought is partly that the smell of this gas often alarms the rats, and they make good their escape; and then again the action of this gas corrodes metal and imparts a disagreeable taste to certain delicate provisions, like tea and coffee, which cannot readily be got rid of (A. Lutrario).

As the danger that threatens the men who carry out this fumigation is a considerable one, a grasp of first-aid measures for the victims is of the first importance. The British memorandum emphasises the fact that the rescuers are also in danger of losing their lives, unless they are provided with gas-masks and safety ropes.

The patient must be carried to the fresh air immediately. Artificial respiration must be carried on for a long time without stopping. The application of other remedies viz. the administration of oxygen, injections of hydrochlorate of lobeline or hyposulphite of sodium, or even of atropine, must be delayed until the arrival of a doctor. The administration of camphor is contra-indicated. If the patient has absorbed cyanide an emergency dose may be administered of 30 cc. of a 25 per cent. solution of ferrous sulphate and 30 cc. of a 5 per cent. solution of soda. If this proves weak, powdered magnesium (2 grm.). The poisoned patient must be made to vomit if possible.

LEGISLATION

Most of the measures laid down deal in the main with safety or the weight of loads (see article "Transport").

In Belgium the Royal Decree of 5 December 1906, forbids, among other things, the employment of boys under sixteen years of age for cleaning out marine boilers; of boys under sixteen and women between sixteen and twenty-one years of age for working cranes or hoisting apparatus; of women under twenty-one for work in the holds of ships; workers are also forbidden to go about ships before they have an assurance that there are no asphyxiating, harmful or inflammable gases about, or before they have taken what precautions in the interests of health are necessary to dispel this danger. Workers going down into the said places must be kept under observation, sent in relays and roped. Workers must be prohibited from sleeping in dangerous places, where emanations might be produced, or where they might fall down, or where there is danger of cargoes being thrown in on top of them, or in close proximity to machinery, to driving wheels, to the motions of transport lines. Workers who have wounds on exposed parts of the body must be forbidden to handle any goods that might be infectious, until the wound has been covered with a dressing. Workers who have handled goods that may possibly be infected must be ordered to bathe the exposed parts of the body with antiseptic.

Other special precautions must be taken with a view to avoiding risks or sickness resulting from handling irritating, corrosive, dangerous or toxic substances. Heads of firms must be the agents and take all steps necessary to supply first aid and transport to the nearest ambulance station.

The Finnish Government in 1929 proposed making the employment of women under twenty-one years of age illegal in certain operations of loading and unloading work on the quayside.

In Great Britain the Dock Regulations of 28 March 1926 forbid the employment of boys under sixteen for working hoists; they make certain requirements as to first-aid boxes, ambulance carriages and the posting up of notices indicating the spot where first-aid boxes, stretchers and ambulances may be found; they also contain detailed measures to be taken for the prevention of accidents.

In Greece the Decree of 12 November 1927, confirming the Decree of 15 March 1926, deals with loading and unloading work in the docks.

In Ireland Regulations for dock work date from 29 October 1926. In May the Maritime Sanitary Regulations provide, to some extent, for the personal protection of the workers in respect of wearing working clothes, gloves and head coverings, and as regards infectious diseases. The Dock Work Regulations, sanctioned by Decree of the Royal Commission No. 9202 of 10 December 1923, lay down measures for the necessary protection from injuries (in Genoa).

In the Netherlands the Decree of 5 September 1916 requires the provision of goggles or suitable apparatus protecting the exposed workers from the action of substances harmful to the eyes, and respirator system; the use of suction apparatus placed as close as possible to the point where gas, fumes and harmful dust are liberated; the provision of drinking water, of non-alcoholic drinks, and of drinks for neutralising the toxic effects of the substances handled, of rest-rooms and dining-rooms, and waiting rooms, lavatories and baths for men whose work exposes them to the action of high temperatures or dust. The regulations deal with the cleanliness of work-places, shipyards and the decks of ships.
The following questions were the object of an enquiry presented to the States Members of the International Labour Organisation:

Indication of the weight, attached to large packages, carried by boat, and also the fixing of a limit above which the weight should be indicated on the package: the protection of workers occupied in loading or unloading ships from accidents due to work on land or on board ship, to the kind of work and also the places where it is carried on, the risks to be guarded against; transport between the quayside and the ship, when the ship is not moored to the quayside; the access to the holds, the height of supporting beams, the lighting of ships; the competence of men occupied in working the hoisting apparatus and machines, the protection of workers when employed near or handling explosive, inflammable, corrosive or otherwise dangerous cargoes; or protection of workers when employed near hoisting beams, the access to the holds, the height of supporting beams, the lighting of ships; the competence of men occupied in working the hoisting apparatus and machines, the protection of workers when employed near or handling explosive, inflammable, corrosive or otherwise dangerous cargoes; or protection of workers when employed near hoisting beams.

From the answers received a Draft Convention was drawn up, and submitted for investigation to the International Labour Conference in 1929. (Cf. documents submitted by the International Labour Office.)

Infectious cases are generally compensated in the same way as industrial accidents by the various Governments. Anthrax is compensated for, according to the International Convention of 1925, as if it were an accident, and this Convention is in force in Belgium, Cuba, Hungary, India, Ireland, Japan, and in the Grand Duchy of Luxemburg. Certain laws on compensation for occupational diseases cover other injuries, e.g. dermatitis due to irritant dust and liquids. In the Netherlands pulmonary affections and peripheral paralysis are found among dockers, and are notifiable.

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**DUSTS, FUMES, AND SMOKE**

**Dusts, Fumes, and Smoke**

French: *Poussières, Vapeurs et Fumées.*

German: *Staub, Dämpfe und Rauch.*

Italian: *Polveri, vapori e fumo.*

Spanish: *Polvo, emanaciones y humos.*

**GENERAL REMARKS**

Any attempt to classify suspensions of particulate matter in air is necessarily arbitrary and the distinction between the various classes cannot be sharply drawn. For the sake of liquid grace, however, three broad classes may be used:

**Dusts.** — Solid particles ranging in size from less then 1 micron up to about 150 microns may be considered dusts. In industry, dust clouds coming within this classification are formed by operations such as the grinding, drilling, and blasting of rock.

**Fumes.** — Fumes signify liquid or solid particles from about 0.2 to 1 micron in diameter formed by physic-chemical reactions such as distillation, condensation, and combustion. Acid mists, ammonium chloride, lead, zinc oxide, and the like can be produced in the form of fumes.

**Smoke.** — To the colloid chemist, smoke means "aerosols" consisting of particles of ultra-microscopic dimensions (0.00 to 0.1 micron). For the purposes of this article, smoke is considered the liquid or solid particles (about 0.3 micron or less in diameter) which are the products of incomplete combustion of carbonaceous matter — as, for instance, gas, oil, or lamp blacks; tobacco, wood, or coal smoke.

Gibbs classifies industrial aerosols in three classes according to their degree of dispersion: (1) *Dusts*, in which the particles are larger than 10⁻³ cm. in diameter; such particles settle in still air with increasing velocity and do not diffuse through a porous partition. (2) *Clouds*, the particles of which range in diameter from 10⁻⁴ to 10⁻³ cm.; such particles settle in still air at a constant velocity dependent upon their size and do not diffuse. (3) *Smoke*, the particles of which range from 10⁻⁴ to 10⁻⁷ cm. in diameter, do not settle at all in still air, diffuse fairly rapidly and are in active Brownian motion.

B. W. Richardson in 1876 suggested classification of the dusts as follows:

- Wounding dusts (hard crystalline: steel, stone, sand, glass, etc.);
- Irritating dusts (wood, horn, textile, wool, silk, hair, etc.);
- Inorganic dusts (poisonous chemical compounds); saline soluble dusts; poisonous organic dusts; irritant and obstructing dusts (coal, flour, etc.).

Layet has classified dusts as follows:

**Mineral dusts.** — Stone dusts (non-injurious): silica, quartz, clay, slate, plaster, sulphur, emery, glass, etc.

**Metallic dusts** (non-injurious): iron,
copper, zinc, poisonous dusts: lead, brass, solder, lime, salts of iron (non-injurious), poisonous salts of lead, of arsenic, of copper and of zinc; lime; caustic salts of chromium.


Organic dusts. — Horsehair, bristles, wool, feathers, hair, bones, horns, silk, etc.

Heim de Balsac and Agasse-Lafont have suggested the following classification: Active dusts: which are immediately disseminated and radiate beyond their point of application: toxic dusts (lead, arsenic, mercury); caustic dusts, chromates, etc.; infectious dusts. Inert dusts: soft flexible felting dusts (wool, cotton, leathers); hard troublesome wounding dusts (ligneous, metallic, stone and coal dusts).

In fact all these classifications are without much practical importance, since in daily practice in industry the harmful effect is more frequently exercised by dusts which are mostly of mixed origin. Besides, what is most important is the physical and chemical constitution of the dusts and consequently their action on the system. An effort has been made to group under the heading "inert" a certain number of dusts, a number which, however, is becoming more and more reduced since certain dusts up till now considered as inert have nevertheless caused serious organic lesions amongst certain categories of workers (talc, asbestos, etc.).

It must therefore be admitted, in common with the majority of experts, that the so-called "inert" dusts are not really inert when considered from the pathogenic point of view. While at the outset they are not harmful, and while even when present in the workroom in large quantities they cause transitory discomfort (sneezing, watering of the eyes, cough), it is certain that in the long run, as the organic reactions diminish and the system does not seem to suffer from the effects, it is nevertheless finally attacked in a subtle manner and sometimes even seriously.

The mucous membrane of the nose, the conjunctiva and first the upper and subsequently the lower, respiratory passages, the teeth, the skin, and often the digestive tract are subjected to the harmful action of the dusts.

Hoffmann in 1908 studied the harmful action of dusts and classified them as follows: metallic, mineral, vegetable, animal and mixed. In 1909 he studied dusts raised in course of scavenger's work (for details see article "Occupational Diseases: Respiratory Apparatus"). Other authorities have limited their attention to the study of toxic dusts (lead, arsenic, mercury, etc.) and irritating dusts affecting the respiratory apparatus, and those which favour the development of fibrosis and pulmonary tuberculosis.

Dusts

The Stability of Suspensions of Dusts, Fumes, and Smoke

Dust suspensions show a gradual decrease in the size of the average particle as the suspension clears up, owing to the fact that the particles settle out, roughly, at rates proportional to their size. The particles of freshly formed fumes and smoke are more uniform in size than dust particles. Moreover, unlike dusts, the average particle in a fume suspension is found actually to increase in size, on account of particle growth.

The rate at which large visible particles (60 μ or larger) settle in still air follows the ordinary laws of gravity. When the size becomes of the order of less than 10 μ, the rate of settling varies directly as the square of the diameter and as the specific gravity (Stokes' law).

Gottfried Seiler (1928) has studied the relations existing between the quantity of dust suspended in the air and dust which has settled. Naturally, the results vary according as to whether there is movement of air in the room or not. Further, the finer the dust the smaller will be the differences in sedimentation at various heights. A study, by the Stokes method, of the speed rate at which dusty particles fall has brought to light the existence of a relation between the diameter of the particles and the rate of sedimentation. Recent American research has established that it is the very fine dust particles of a maximum diameter of 10 μ which penetrate into the alveolii. Now the rate found by Seiler of 1/3.6 for elements of 10-15 μ in diameter proves that it is the particles the sedimentation rate of which is lower than this figure which are harmful to the lungs. The danger of penetration into the pulmonary alveoli will be the greater according as to whether this rate diminishes in the direction of zero.
The fact that still-air conditions do not generally occur in industry does not seriously affect the value of the observation that stable suspensions are necessarily made up of small particles and that large particles can be suspended only momentarily in still air (fig. 59).

Particles of some freshly formed fumes like zinc oxide have a tendency to form flocculates or groups, held together with a certain orientation by invisible links which possess a strong cohesive force. This force is so great that considerable mechanical energy and special dispersing media are often required to break up the flocculates.

If the particles are liquid, like those of tobacco smoke and acid mists, flocculation causes the formation of larger droplets. Almost any method which promotes flocculation is effective in reducing fume and smoke concentrations, because the flocculates have sufficient mass to overcome the buoyant effect of the suspending medium (air), whereas the single particles float about easily in slight air currents. Dense suspensions of fumes and smoke are more unstable than dilute suspensions, because their particles are more likely to collide. Turbulent air currents (fig. 60) also promote flocculation and cause fume and smoke suspensions to clear up more rapidly than they would in still air.

Dust particles suspended in the air as the result of drilling, crushing, or blasting of rock are much less active physically than fume or smoke particles. Turbulent air motion does not appear to accelerate the rate at which silica clouds, for example, clear up (fig. 61). Jets of steam or very finely atomised water, which condense upon the particles of the dusts or fumes (fig. 60 and 61), usually promote flocculation and assist materially in removing such particulate matter from the air. In mines, water blasts are used to allay dust, both at its source of generation and after it has become dispersed in the air. Removal at the source is the more effective, but dust removal is never complete — the more dilute the suspension, the less effective the water blast.

The deposition of soot and smoke particles on the insides of chimneys is a familiar annoyance. The extent and effectiveness of such deposition ("thermal precipitation") depends upon the difference in temperature between the suspension and the object on which the particles are to be caught. Smoke particles from the hot exhaust of auto-
mobiles or smoke from hot chimneys can be collected in this way, and, under properly controlled conditions, the method is quantitative.

Dry, finely divided particles of all sorts have a tendency to entrain air or other gases in amounts which increase notably with decrease in the size of the particles; a 50 kg. package of 0.15 μ zinc oxide, for example, is appreciably larger than a package of 0.8 μ zinc oxide of equal weight.

Aqueous colloidal solutions of the weakly basic or weakly acidic compounds are charged respectively positively and negatively. Suspensions of the common dusts and fumes in air show precisely the reverse effect; thus particles of alumina (Al₂O₃) suspended in air are charged negatively and silica (SiO₂) particles are charged positively. It is therefore possible to speak of alumina as a negative and silica as a positive dust.

**Fig. 62.** — Size-frequency relations plotted on logarithmic probability paper. Line A = phagocytosed particles found in human sputum. Line B = silica particles from ashed lungs of South African miners.

**Sampling and Estimation of Dusts, Fumes, and Smoke**

There are many occasions when practical and reasonably accurate methods for estimating dustiness are required. Often the entire amount of suspended matter in any given volume of air need not be determined — a fraction of the total suffices, if it is known by previous controls just what percentage of the total has been caught.

In every case, concentrations should be given in terms of the amount (the weight or the number of particles) in a measured volume of air with the size-distribution of the particles (fig. 62). No rules governing the permissible error or the method can be laid down, because the conditions differ too widely. Although no one method will apply satisfactorily in every instance, a number of methods which have passed the experimental stage can be suggested.

**Settlement**

The particles collecting in a moistened trough of known area are collected over a specific period of time. This method has long been used by weather bureaux in various countries for determining atmospheric pollution by smoke. The objection that the results of the determinations depend upon the whim of air currents is met by using several apparatus at different places. The results are relative rather than quantitative, but the method is simple and sufficiently accurate for much routine sampling.

A more precise quantitative method has been recently developed in which a definite measured volume of air is trapped in a suitable container and the particles which settle to the bottom are estimated.

**Filtration**

For estimating coarse, dry suspensions like grain and other inflammable dusts, methods which involve no fire hazard are essential. Moreover many of the particles are comparatively large (10 μ to 75 μ), they settle out quickly, and rapid sampling is therefore desirable. In such instances, the use of paper extraction thimbles is recommended. The weight of the thimble is determined before and after a known volume of dusty air has been drawn through and the increase in weight is noted.

Soluble filters, like sugar, have been extensively used in determining the inorganic dusts in mine air. In this case, where the particles to be estimated are usually under 10 μ, sugar has a filtering efficiency of about 70 to 80 per cent. The dust collected on the sugar from a measured volume of air is separated by dissolving the sugar in water and filtering off the insoluble dust.
Impingement
(Greenbury-Smith Method)

If dusty air is blown through a fine tapered tube pointed vertically against a wet surface and close to it, most of the particulate matter in the air (about 93 per cent.) is caught by impingement against the wetted surface. The optimum distance of the tip of the tube from the wetted surface, the best wetting medium (usually water), the optimum air velocity or rate of sampling, the optimum size of tube and other practical details have been carefully worked out. For suspensions of common dusts, samples are taken at a rate of 24 to 32 litres a minute, but there is no reason why the method should not be adapted for sampling at higher or lower rates. The impinger is being widely used to-day in the United States, especially by the U.S. Bureau of Mines and the U.S. Public Health Service.

Other Methods

Reference may here be made to certain methods applied in Europe. Allken's konimeter acts as follows. A given volume of dusty air is aspirated in a small chamber and diluted with a more or less considerable quantity of air purified by filtration. The air is humidified by means of blotting paper dipped in water and then raffted by suction. The sudden cooling produced by the expansion of air also causes super-saturation of the air. The excess of steam is condensed on the fine particles of dust forming the centre of condensation, which then fall on a micrometer attached to the instrument. It is then possible to read on the squares of the micrometer by means of a magnifying glass the number of droplets condensed on each dust particle.

Allken, during his investigation into conditions in linen factories, adopted a very simple procedure for evaluating the dust present: the apparatus which he uses consists essentially of a glass funnel, the interior of which has been rubbed with emery to hold in place two corks placed one over the other, the surfaces in contact being polished. Between these is introduced a thin celluloid plate about 1/10 mm. in thickness. The surface of this plate is coated with a thin layer of sterile gelose. The corks have a central circular aperture of 20 mm. in diameter in the case of the upper cork, and 16 mm. in the case of the lower cork. The sheet of celluloid is perforated in the centre, having 25 holes uniformly distributed over a surface of 1 sq. cm. At the outside of the neck of the funnel an etched surface forms the stopper for a flask with a double set of tubes, the second of which connects up the apparatus with a dust exhaust system which functions by means of water displacement.

The dust particles deposited on the celluloid plate are examined microscopically and their form and number determined. The experiment may also be extended by incubating the celluloid plate and estimating the bacteria developed.

The method of Tissandrier is based on an evaluation of the weight of the dust collected. In 1899 Bontemps also utilised a similar method, his U-tube being filled with cotton-wool instead of asbestos.

Gemmy in 1927 utilised for calculation a current of air and dust which was directed against a glass screen of 1.5 to 2 mm. in diameter, the surface of which had been moistened with castor oil. The dust stuck to this and could be analysed either microscopically or chemically.

In the same year Seitz suggested a comparative photographic method by means of photographs of standard dusts presented on celluloid plates. These photographs are prepared in the laboratory with varying quantities of metallic dust (5 to 100 mg.). For the purposes of practical research in the factory similar celluloid plates are used, the surface being coated with a layer of albumin and glycerine or liquid paraffin with a view to causing adhesion of the particles of dust to be studied. The plates containing the dust are then photographed; only inorganic dusts are revealed in the form of shadows with cutting edges. They are then compared with the standard dust plates.

Jet Condensation Methods

The Kotze konimeter has been extensively employed in the South African gold mines. A jet of dusty air, 10-15 cc., is driven at high velocity (about 80 metres per second) against a vaselined slide by means of a small spring-actuated pump. The dust particles caught upon the slide in the form of a circular spot are then counted under a microscope equipped with a net-ruled ocular. The "circular" konimeters permit the taking of numerous "spots" which are distributed in the form of a circle on a single slide. A convenient form of pocket micro-
scope with which dust counts can be made in the field at the time of sampling is also available. For the routine dust sampling of mine air, the South Africans use this method extensively, and, since they have done more than any other single group to show the value of routine dust sampling, their endorsement of the konimeter is important.

For studying atmospheric pollution from the meteorological standpoint, a more delicate and accurate instrument, the "jet dust counter" has been devised. Dusty air is held momentarily in a dampening chamber and then drawn violently through a fine slot (0.5 cm. by 1 cm.) against a clean, dry microscope cover slip. The high velocity (250 metres per second) through the slot and consequent reduction in pressure cause condensation of the moisture upon the dust particles, which stick in the form of a fine ribbon upon the cover slip. The condensed moisture then evaporates, leaving the dust ribbon dry. A suitable fraction of the particles on the ribbon are counted under a microscope equipped with a net-ruled eyepiece, the oil immersion objective being used.

Both konimeter and jet dust counter can easily be carried in the pocket of one's coat and consequently they are particularly well adapted for sampling in inaccessible places. The Owens' counter is the more sensitive of the two; it is ideal for taking dust counts in normal out-of-door air. As they are now constructed, both instruments are unreliable when the dust cloud is dense enough to produce "ribbons" or "spots" in which the individual particles are piled up and indistinguishable. There is no reason, however, why they could not be modified for use in very dusty air.

Electric Precipitation

If a tube of glass, quartz, or other dielectric is wrapped with a metal foil and a fine wire passed through its full length and held centrally, high tension alternating current, applied at the metal foil and central wire, will cause most of the particles of dusts, fumes, or smoke within the tube to precipitate against the inner walls. The remainder (about 2 per cent.) will be caught on the centrally aligned wire. Precipitation is complete only if the suspension is drawn through the tube at a certain rate, varying with the suspension, the voltage applied to the terminals of the precipitator tube, and the constructional details.

If a thin, transparent foil of celluloid is placed within the precipitator, the dust, fume, or smoke particles will collect upon it and, from their distribution, the effectiveness of the precipitation can be judged (fig. 63).

The precipitation method is advantageous because of its effectiveness against both fine and coarse suspensions and the fact that its efficiency at any time can be estimated. The particles are precipitated in the dry state, and strips can be cut from the celluloid foils and mounted immediately for microscopy.

On the other hand, the precipitator utilises voltages varying from 5,000 to 20,000 and is a rather heavy and expensive piece of apparatus. It is clearly unsuited to work in mines and other inaccessible places, but it is adapted for use in factories and like places, where electric current is available.

Photometric Methods

If a suspension of dust, fume, or smoke is passed across a beam of light, the amount of light (a) reflected by or (b) transmitted through the suspension gives a useful measure of density. This principle has been utilised in the Tyndall-meter for studying fumes and smokes.
in the contrast photometer \((h)\) (fig. 64) for studying atmospheric pollution, and in another light transmission method \((b)\) for observing the density of automobile smoke in vehicular tunnels. Results obtained by Tyndallimeter and contrast photometer are shown in figs. 59, 60, 61 and 64.

The advantage of these methods is the rapidity with which readings can be taken — a matter of one or two minutes only. Actual concentrations can then be calculated by comparing the results with standards previously established from known concentrations. The usefulness of photometric methods is limited by the fact that the results are materially affected by the colour, size, shape, and refractive index of the particles and become inaccurate when the suspensions are too concentrated or too dilute.

**The Physiologic Effects of Breathing Dusts, Fumes, and Smoke**

When dusts, fumes, or smoke are breathed, only the portion which is retained has physiologic significance. From experiments on man, it has been found that, in dusty air, the amount retained is approximately 40 to 60 per cent, of the total inspired — the remainder is expired. Although these experiments do not show directly whether the retained particles reach the alveoli or are caught in the upper respiratory passages, they indicate that slow, deep breathing causes greater alveolar penetration than rapid, shallow breathing, which is, of course, the normal physiologic expectation. It appears to make little difference whether the suspensions are inspired through the nose or through the mouth; the dust catching efficiency of both routes is very poor.

The small particles \((0.50 \mu \text{ and less})\) which are always present in expired air and also in alveolar air may ordinarily be ignored. When the action of the dust takes place in the alveoli and not in the upper respiratory passages or the gastro-intestinal tract, it may be desirable to sample the alveolar dust. This can be done by a method which makes use of the Owens' jet dust counter and the Haldane extension tube for sampling carbon dioxide in alveolar air.

**Dusts**

The hygienically significant dusts (particles from about 0.5 \(\mu\) to 150 \(\mu\)) may be considered under three classifications:

(a) Dusts which are specifically toxic and comparatively rapid in their manifestations, but which do not cause lung fibrosis.

(b) Dusts which cause lung fibrosis (pneumoconiosis) after several years' exposure.

(c) Dusts which are non-toxic and do not cause fibrosis.

**Toxic Dusts**

The inhalation of organic dusts — wood dust and the pollens of flowers, for example — frequently causes diseases like asthma and hay fever. The particles producing these effects are often large enough \((15 \mu \text{ and more})\) to prevent penetration into the alveoli and too large to be phagocytosed.

Manganese poisoning, resulting from the inhalation of manganese dusts and their subsequent entry into the gastro-intestinal tract, has been known for a number of years. The dust generated by the mining of cinnabar, the common ore of mercury, is sufficiently hazardous to demand rigid control of the process and diligent medical supervision of those employed.

Traces of radio-active salts in significant amounts were found in the air of a plant where radium paint was applied to the hands and dials of watches. The inhalation of dusts from lead compounds and lead ores is also hazardous.

Many more examples of like nature could be given, but the important observation which holds true for them all is that the particles of toxic dusts which do systematic damage are those which are small enough to be carried by moderate air currents. Their action is generally specific and therefore...
their presence in the air constitutes the hazard. Whether their toxicity is manifested in the lungs, the upper respiratory passages, or the gastrointestinal tract is a secondary consideration.

Dusts which Produce Pneumonoconiosis

A specific pathological condition of lung fibrosis results from inhaling, over considerable periods of time, logically inert, chemically insoluble, and physically inactive. The pneumonoconiosis produced by inhaling them is termed silicosis. Whether other pneumonoconioses (as anthracosis from coal dust, or siderosis from iron dust) are pathological entities and definitely distinguishable from silicosis seems doubtful.

Cases of pneumonoconiosis are generally found among workers with histories of long exposure to dusts which contain appreciable amounts of excessive amounts of certain dusts (figs. 62 and 65) with particles ranging from 0.4 μ to 6 μ.

The dusts which are most injurious are usually found to contain a high percentage of free, acid insoluble, crystalline silica and proceed from the drilling, crushing, cutting, and polishing of such minerals as quartz, flint, and sandstone. Moderate doses of these substances, taken by mouth, would ordinarily be considered toxic.

Fig. 65. — Mineral dust particles in unstained endothelial cells from men exposed daily to the dust of several different minerals. Approximately X 1500. (Photographs taken by Henry Green, Research Laboratory, the New Jersey Zinc Company, Palmerton, Pa., U.S.A.)

Figures 1 through 6 illustrate the presence of these particles in various types of dusts.

The theory that pneumonoconiosis is
caused by the sharpness or hardness of the particles breathed has been refuted rather convincingly. The artificial abrasives, aluminium oxide (Al₂O₃) and silicon carbide (SiC), are harder than quartz, but apparently do not produce fibrosis. Moreover it is a question whether pure silicates like talc, cement, and asbestos, in the absence of free silica, produce fibrosis. Even when free silica is present in moderate amounts in these dusts, their action is much less harmful than that of quartz or granite.

The commonest carbon dust to which large numbers of workers are exposed is coal dust. Anthracite coal, as it is found in Pennsylvania and Wales, may contain 92 per cent. of carbon, but the dust generated in mining and handling it may be contaminated with outlying rock in sufficient amounts to introduce a silicosis hazard. Cases of pneumonoconiosis in men who are exposed to such dusts are common, although the hazard is generally much less serious than that encountered in granite cutting.

The reason why pneumonoconiosis is dangerous, especially in its advanced stages, is that it usually terminates in a fatal type of pulmonary tuberculosis. The predisposing agent is the dust and the likelihood that tuberculosis will develop from the pneumonoconiosis seems to vary definitely with the free silica content of the dust. In the light of present knowledge, it is possible to diagnose three stages of pneumonoconiosis by X-ray. If a patient is removed from exposure to the dust before pulmonary tuberculosis sets in, he may be saved from the final stages of the disease, but even this expedient is not always reliable.

It should be remembered that dusty industries like the manufacture of Portland cement (where talc is used) and asbestos products are quite modern. If ten years' exposure to quartz dust and twenty-five years' exposure to granite are required for an average case of pneumonoconiosis to develop fatally, it is not surprising that it is not yet possible to evaluate the dust hazards in some of the newer industries. Moreover, the recognition of pneumonoconiosis as an industrial disease and the application of the chief diagnostic method, the X-ray, are themselves comparatively recent.

The need for further study on the action of silica dusts is evident. Surface tension, phagocytosis, and solution — all factors in the removal of dust particles from the alveoli — are primarily surface effects. It is known that positive dusts (silica) are wetted preferentially by water and negative dusts (alumina) by oils. Different dusts are phagocytised in vitro with varying selectivity and granule particulates, for instance, are phagocytosed about three times as readily as quartz particles of equal size. Colloidal silica, injected intravenously, has been shown to be specifically toxic and to produce fibrosis. Promising results have recently been obtained by sub-cutaneous introductions of crystalline silica (as mine dust). Through the development of rapid methods of dust determination (see above) and the use of 5 to 10 per cent. of carbon dioxide in the dusty air, it is possible to carry on dusting experiments on men and animals with very nearly the precision of gassing experiments.

It is hoped that these and other lines of investigation will throw so much light on the problem that it shall no longer be necessary to rely solely upon mortality and morbidity statistics of the dusty industries for evaluating pneumonoconiosis hazards and determining permissible or threshold dust concentration.

**Non-Toxic Dusts**

Dusts like carbon, gypsum, talc, asbestos, magnesia and the like are not specifically toxic and it is doubtful whether per se they produce lung fibrosis. Usually, however, these dusts do not occur in the pure state, but are contaminated with enough free acid insoluble, crystalline silica to constitute a silicosis hazard.

The over-dusting of animals in laboratory experiments may cause severe oedema of the lungs and death from pneumonia. In man, severe exposures to non-toxic dusts may cause temporary bronchial and tracheal irritation and violent coughing, occasionally accompanied by nausea.

It is doubtful whether such conditions occur often enough to constitute a serious hygienic problem, although erroneous conclusions have been put forward as the result of the over-dusting of animals.

1 Gundermann In 1928 directed attention to the quantity of dust raised in workrooms where the polishing of steel ball bearings was effected, certain of which employ tools of a very ancient pattern and have very inadequate dust-removal systems, while others have up-to-date installations with adequate dust exhaust systems. A similar study has been made by Gundermann in the woodworking industry. It is desirable that similar research should be engaged in relation to other varieties of dust (glass, sand, etc.).
Dusts, Fumes, and Smoke

Abnormally high death rates from bronchitis and pneumonia, are sometimes attributed to chronic exposures to non-toxic dusts, and an amazing amount of dust is occasionally found in supposedly normal lungs at autopsy, yet it is not possible at the present time to give even approximate figures for lethal or dangerous doses.

Dust Explosions

Reference is made below only to those dusts which most frequently cause explosions. They are as follows: dust from coal, cotton and grain (in course of ginning and threshing); these are attributed to particular atmospheric conditions and especially to the presence of spores of *Tilletia Tritici* in threshing grain ignition of which is generally due to the formation of electrostatic sparks. Dust from flour (mills), from grain (elevators), from starch, dextrin, etc., from rice (mills), from malt (breweries), sugar, wood, albuminoids, celluloid, cocoa, copal, gum magnesia, paper, rubber, "shoddy", soap, sulphur, spices, tan, copal, gum magnesia.

It is known that when matter reaches a certain degree of dispersion — in the chemical-colloidal sense of the word — it tends to assume special characteristics; dust, that is to say, when in a state of suspension in an element (atmospheric air in most cases) assumes a mobility reminiscent of that of gas molecules, analogous, in certain cases of extreme subdivision, to the Brownian motion. The volume it occupies is therefore a very considerable one, and its superficial area increases very rapidly. The mass then acquires a greater power of floating in a dispersing medium without being able to settle. Finally, dust, owing to its superficial area and low density, which enable it to mingle with the dispersing medium, displays increased physical and chemical activity.

It has been seen above that dust may be produced by condensation of a vapour (fog or mist is then formed) or smoke, or, what is more frequently the case, by disintegration and the fine dust that escapes is electrically charged. If machines of this kind are not earthed, and if they become charged under favourable conditions, particularly in very dry weather, a spark discharge may occur with disastrous consequences. In presence of charges of over 10,000 can easily be accumulated, and this danger must be combated by humidifying the air or by introducing suitably earthed collectors.

Dust may become charged as a result of friction against solid surfaces in machines, and the fine dust that escapes is electrically charged. It machines of this kind are not earthed, and if they become charged under favourable conditions, particularly in very dry weather, a spark discharge may occur with disastrous consequences. In presence of charges of over 10,000 can easily be accumulated, and this danger must be combated by humidifying the air or by introducing suitably earthed collectors.

Thus is every advantage in industrial practice, with a view to combating the inherent dangers, in transforming aerosols into aerogels as rapidly as possible after their formation. The types of dust precipitation apparatus to be adopted must take account of the stability and flocculation of aerosols. While settling of the dust is attained in a simple manner by the use of shock-producing apparatus by forcing the particles into violent contact with a baffle, or by centrifugal methods, etc., it will, on the other hand, be necessary to certain bales or by electrical/mechanical methods are inoperative (owing to great dispersion or disintegration of the matter) to have recourse with a view to precipitation, to a variation of electric charge which protects the particles or which tends to displace the atmospheric cushion by which they are surrounded, favouring flocculation of the aerosols. The
application of this principle is found in the Cottrell method (see later). There is a great similarity between gas and dust explosions, both in their causes and in their effects. In both cases there are two distinct phases in explosive combustion; ignition and propagation. Aerosols whose particles offer a large superficial area, and which are in close and intimate contact with the atmosphere in which they are dispersing, display gases a marked tendency to explosive combustion; yet phenomena of ignition and propagation are smaller in the case of gases than in that of dust. As in the structure of the former is always less dispersed. On the other hand, the aerosol liberates greater heat, since per unit of volume, it contains more inflammable matter.

Numerous experimental studies of explosive dusts have been effected in Austria, Belgium, France, Germany, Great Britain, the United States, etc.; in certain of the large coal mines in Britain and in others smaller stations of experimental mines have been fitted up.

Experiments conducted with a view to studying ignition temperature have resulted in differentiating the dusts into three classes: (a) dusts which ignite and propagate flame readily, the heat source required for ignition being comparatively small (the most dangerous are sugar, dextrin, starch, cocoa, cork, wood-flour, grain dust, dust from coal briquettes, etc.); (b) dusts which are readily ignited, but which for the propagation of flame require a source of heat at a large temperature as high as the flame of a Bunsen burner (these include copal gum, leather, "dead" cork, sawdust, bran, horn-meal, "shoddy", etc.); (c) dusts which do not appear to be capable of propagating flame under any conditions likely to obtain in a factory (these include organic and inorganic non-combustible dusts, such as ash, grain cleaning which are more or less readily inflammable, and dusts of coke, graphite, bone-charcoal, mineral and ivory black which are almost harmless.

Amongst the factors by which dust explosions are caused may be mentioned pressure. This pressure increases pari passu with the concentration of the dust as it approaches the limits of chemical combination with oxygen, with the degree of dispersion, with the porous structure of its particles, enabling the gas to be more readily adsorbed, and lastly with its lower tenor in humidity. Other factors are the degree to which aerosols are subject to oxidisation, increase in the content in volatile substances, the nature of the source of ignition, spontaneous ignition or ignition caused by a thermic or electric source.

A deciding distinction must, however, be made between the explosive phenomena occurring in industrial establishments and in mines. In the latter case the explosion occurs in galleries which are not subject to collapse or destruction, and through which pressure spreads at a relatively high speed. While, therefore, the material damage is comparatively small, the loss of human life in the crowded underground places often attains the proportions of a disaster.

In mines the necessity for thorough ventilation, the traffic along the roads, the presence of combustible agents in the mine, the movements of the workers, all contribute to raise dust which is constantly in suspension, filling even the furthermost corners. The fact was first established about 1907 that mine explosions and their violence were not due to methane (fire damp) alone, but that coal dust was also largely responsible.

Coal dust explosions depend on the physical and chemical properties of the coal (its content and humidity, volatile matter and cinders). Experiments have shown that the presence of 90 per cent. of water renders any bituminous coal dust non-explosive. The concentration and the fineness of the dust produce the same effects as in the case of other aerosols. Explosions cannot occur when the content of the atmosphere and oxygen is less than 18 per cent., and the figure is even lower when methane is present. The velocity of the pressure wave set up when an explosion occurs must exceed 170 miles per hour to raise the dry coal dust necessary for its propagation.

As the best means of preventing explosions and their propagation, the following have been recognised. Frequent cleaning of the mine, failing which, special zones kept entirely free from dust, to prevent the effects of the explosion spreading through the zone (this method is not very effective); reduction of the oxygen contained in the air in the mine to 17 per cent. (only suitable where no methane is present); wetting the dust with water (a better and most extensively applied method); projection of chloride of calcium or similar deliquescent salts; increasing the percentage of incombustible matter in the dust by distributing throughout the mine suitable inert dust (stone dusting). This latter method constitutes by far the greatest advance for generations in the attempts made to safeguard mine workers. The use of light-coloured dusts is recommended, as it enables the supervisors to see at a glance whether the requisite precautions have been properly carried out. On the other hand, dust liable to injure the respiratory
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organs should be avoided. The percentage of inert dust in a mine should be subject to strict daily control and analysis.

Dust barriers are more adapted to prevent the spread of explosions than their formation. The use of both methods (stone dusting and dust barriers) in conjunction with, and suitably adapted to, local precautions are advisable. The addition of inert dust is more effective than wetting, owing to the length of time it lasts, and it is also less costly (see also article "Mines, Hygiene in ").

The causes of dust explosions in factories are the production of a dust cloud, of concentration lying within explosive limits, which may be formed gradually or suddenly, and the introduction of effective sources of ignition. Amongst the latter, fires or open flames, generally due to carelessness on the part of the workmen, or to the accidental breaking of an otherwise protected lamp, or to the close proximity of gas engines or steam boilers, towards which a cloud of dust is carried by a draught; proximity to spark-generating surfaces may also cause the dust to be overheated, a factor liable to produce spontaneous combustion, without direct ignition. It may also be due to contact with overheated bearings or to excess friction, or simply to contact with overheated lamp glass, etc. There should be mentioned also in this connection sparks produced by friction, or shock contact between two metal surfaces (sparks struck by workmen's tools, rupture of a crushing part of a machine, the accidental introduction of a piece of iron or other hard material into a crusher). Electric arcs are generally caused by the breaking of electric lamp bulbs, by the fuses of electric motors blowing out, by short circuits in the winding of motors, by faulty winding or merely by the breaking circuit. Sparks of static origin result when charges of opposite sign form on the particles of an aerosol and on the parts of the machinery in which they are moving. Sometimes it is impossible to say to which of the causes the explosion is due.

The explosions due to dust can always, under moderate conditions, be reduced to a minimum, or even prevented. Methods of prevention are applied with a double object — prevention of the occurrence of explosions and prevention of the spreading of their effects.

The most fundamental protection is to ensure perfect cleanliness of the factory and plant. Dust should be removed by exhaust, and effected by apparatus based on the same principle as the ordinary household vacuum cleaner, rather than by the application of the very ineffectual methods of sweeping, brushing, or by the passage of compressed air.

Naturally, every effort should be made to ensure the reasonable removal of dust raised by machinery (mills, sieves, boiling machines, grind-stones, wood-working plant, saws, etc.) as well as to ensure dust elimination by methods referred to later.

Fumes

A definite type of febrile reaction follows the inhalation of certain metal fumes. This reaction cannot be ascribed to specific toxic properties of the fumes and seems to occur only when the fume particles are very small (0.2 μ to 1 μ). (See also article "Gas and Fumes ".)

Metal fume fever has been produced by the oxides of zinc, copper, cadmium, and magnesium; mercury; manganese dioxide; the sprays of many metals and metal compounds; and probably fume oxides made by burning aluminium, iron, and chromium. (See articles "Copper ", "Brass ", "Zinc ".)

Metal fume-fever is most commonly found among men who are engaged in the skimming and pouring of molten brass. These processes cause an evolution of dense clouds of zinc oxide fume, contaminated with small amounts of copper and traces of lead, cadmium, and other substances contained in the brass. Threshold concentrations of zinc oxide fume and measures for preventing chronic attacks of the fever have recently been suggested. Fatalities from breathing zinc oxide have not been reported, but there is evidence that frequent attacks of the fever produce a slight general debilitation. Surveys and statistical studies upon brass workers have indicated a high tuberculosis rate; but, since the groups examined included buffers, polishers, core makers, etc., who undoubtedly were subjected to a pneumonoconiosis hazard, it is impossible to say with any assurance that the high tuberculosis rate was caused by the metal fume fever alone.

Although zinc oxide fume is the one most commonly met with in industry, mercury, copper, manganese dioxide fumes, and the like, produce their own typical pathology, if exposures are frequent and sufficiently severe.

Toxic Fumes

If atomised or vapourised, hygroscopic chemicals will cause fogs or mists, particularly in humid atmospheres. Fogs from sodium chloride, potassium chloride and ammonium chloride can be produced in the laboratory, but the acid mists from hydrochloric and sulphuric acids and from sulphur trioxide are the examples most commonly found in industry. These three substances, and others of like nature, are markedly astringent and cause violent coughing or nasal
irritation, which usually prevents the occurrence of accidents from breathing them in dangerous concentrations.

Lead fumes, on the other hand, have created a serious health hazard, well recognised since the early smelting of lead ores. Lead burning and the spraying of lead paints have introduced new risks; but, if proper precautionary measures are taken, there is no reason why both of these operations cannot be carried on with safety. (See articles "Gas and Fumes" and "Soldering (Lead)").

Smoke

Since the early history of the use of coal (and later of oil) as fuel, protests and legislative action have been directed against the smoke nuisance. The complaints have been based upon wastage of fuel (poor combustion), the corrosive or toxic effects of the gases mixed with the smoke particles, the cost of cleaning buildings and household materials, the aggravation of fog and haze, and, more recently, interference with the visibility desired in aviation.

Although there is as yet no convincing proof of the harm done by breathing the smoke and soot particles contained in the air of our large industrial cities (concentrations of 0 to 3 mg. per cubic metre) (see fig. 64), the development of radiation therapy gives an effective hygienic argument against smoke — that it filters out a substantial portion of solar ultra-violet radiation.

In Great Britain, a department of the Air Ministry records and estimates smoke pollution in the important industrial communities as a part of its routine duties. The universal adoption of this practice and the development of a satisfactory instrument for recording solar ultra-violet radiation should show very definitely the extent of the smoke nuisance in its relation to health.

G. J. Shott (1927) has described three apparatus constructed for the same purpose as the "Orsat" apparatus for the automatic analysis of gases and smoke. The apparatus in question are designated "Co Coo", "Duplex Mono" and "Unographe". According to the experiments engaged in by this expert, he is of the opinion that the first two are to be specially recommended as they provide results correspondingly to those of the apparatus "Orsat", which demands strict attention on the part of the operator and also much time. The third has not so far been sufficiently used to admit of an adequate estimate of its value.

On the other hand, the Health Committee of the International Chemical Union suggested in 1924 the establishment of a maximum acidity coefficient for smoke at the moment of its dispersal. This acidity content has been fixed at 5 grm. per cubic metre in Germany, 8 grm. in Great Britain, 6 grm. in Italy, the quantity being expressed in SO₂. The Committee in 1925 adopted the procedure proposed by Denmark, that is to say, that the acidity of smoke and gas (except that arising from carbon monoxide) should be expressed in equivalent grammes. This acidity should be measured at the point of dispersal of gas and smoke and expressed as the rate per cubic metre. The Committee recommended that the maximum acidity permitted in smoke, fumes, and gas should be established for each country at 0.16 equivalent grm. per cubic metre at 0° and 760 mg.

In order to obtain the necessary draught for withdrawal to the chimney of the carburetted air a high chimney is used or an apparatus with natural draught or provided with ventilator having a mechanical draught. The latter is often necessary as a result of resistance due to a smoke circuit and to the volumes of smoke requiring to be dealt with.

The natural draught may be improved by apparatus which produces automatic withdrawal within the chimney (Chanard, Prat, Marelli types, etc.). Other types are utilised according to need for the provision of mechanical draught. The chimney is furnished with a ventilator acting as diffuser. The smoke-consuming apparatus are blowers of air or steam more or less mixed with air in order to improve combustion.

The increasing use of combustion agents in pulverised form raises the question of dust elimination from smoke (see below, under Hygiene).

The production of electric energy by means of thermic distributing stations consuming large quantities of coal is at the present time a very important cause of smoke production and thus of dust production. Thus, for example, one of these distributing stations in the neighbourhood of Paris ejects so much dust from its chimney that the amount which falls to the ground attains to 1 1/2 kg. per square metre in a month.
A film purifier consists in intercepting the passage of the smoke by means of fine films of a viscous liquid—some kind of oil, for instance. The dusts adhere to this oil by capillary attraction and they are withdrawn in it and may be collected and subsequently decanted. In practice the oil is directed to the exterior surface of tubes placed in chequer pattern across the current of the smoke.

The problem of suppression of noxious smokes, of soot, ashes and cinders produced by insufficient combustion or defective plant is of very particular interest for industries situated in thickly populated urban areas or in the neighbourhood of cultivated fields.

Whatever be the nature of the smoke (coal smoke, smoke composed of sterile dusts produced in plants burning pulverised coal) the same problem arises, namely, that of preventing its production or that of eliminating it once it is produced.

For sterile varieties of smoke the problem is confined to means of destroying them by interposing between the chamber of combustion and the chimney various apparatus such as baffle plates, currents of water or electricity or a water spray. These are the only effective means, though they involve considerable expense for small factories.

In the case of coal dust the means adopted are mostly those chosen with a view to preventing production. The smoke is directed to a second coke hearth, where complete combustion is effected. This procedure is especially indicated where the production of smoke is inevitable (metallurgical furnaces requiring a reducing atmosphere).

The production of smoke is prevented by employing fuel weak in volatile substances, such as gas coke or similar products. The use of lean and cheap fuel, wherever technical requirements permit it, effects an economy which is sometimes considerable. At the present moment the production of semi-coke of this kind by the distillation of heavy coal at low temperature is the subject of interesting research, with a view to supplying industry with a choice of smokeless fuels.

When the use of such fuels is not possible, the disadvantage resulting from smoke may be eliminated or at least reduced by assuring complete combustion; quantity of air adapted as exactly as is possible to the weight of coal to be burned, good stoking (regular and frequent stoking utilising small quantities of fuel at a time, avoiding accumulations at certain points and lack of fuel at others, manipulation of the air supply with a view to assuring during stoking the admission of a greater quantity of air). Good results are, however, not always obtainable except in the case of plant of a certain size.

Legislative measures have been issued relative to the pursuit of the smoke abatement campaign in several countries. Thus, for instance, in Great Britain, thanks to the efforts of the Smoke Abatement League of Great Britain, founded in 1909, certain items in the Act of 15 December 1926 may be considered as the last word in this respect. The Act, which modifies in part that of 1875 relating to public health, which already contained certain sections relating to the smoke problem, gives a more general definition of the word "smoke". It is stated that the term in question must also comprise soot, ashes and cinders, as well as smoke properly so called, and that henceforth there is extended to all types of smoke causing inconvenience, the prohibition formerly limited to black smoke only, whilst in the case of the latter there is no longer admitted as an excuse for its production the assurance that the plant has been established and is conducted under the best conditions, to which effect may be given in practice.

Fig. 66.—Goggle lens with emery embedded in it, after three months’ use by a grinder operator. (By courtesy of the General Electric Company, Lynn, Mass., U.S.A.)

1 Taken from the report of the Committee on Smoke of the Health Congress of Paris (1928).
Finally, the Act provides, amongst other measures, for the possibility, and even at times the obligation, on the part of the local authorities of defining what is locally meant by "smoke causing inconvenience". In the case of neglect on the part of local authorities, they may, under the Act, be replaced by the County Councils, and the maximum penalties heavily increased. The Act as such is applicable to industry, and provides for the exceptions already adopted in the Act of 1875, with power on the part of the Minister to increase these within a period of five years, or to reduce them, according as to whether technical progress indicates this possibility or vice versa. The law is equally applicable to river steamers, and may be extended to cover certain categories of recent constructions. It does not, however, affect sea-going steamers or private habitations.

In France regulations for control of factories likely to emit smoke are entirely different, according as to whether it is a question of dangerous trades (établissements classés) and consequently as such coming within the general regulations contained in the Act of 1917 or of the remaining industries outside these regulations.

In the first case, any adequate measure may be applied by orders affecting the category in question (first and second categories) or by the general orders affecting a special department in all similar establishments (third category). Sanctions are provided, and in case of a recurring offence the administrative authority is empowered to close down temporarily or even definitely the establishment in question.

For those establishments not coming under the designation "dangerous trades" the Act of 1917 confers authority on the prefect to intervene after notification by the Mayor and the Health Council. In the Department of the Seine there exists an Order, dated 22 June 1898, applied in virtue of the Act of 16-24 August 1790, which prohibits in Paris the continued emission of thick black smoke; a Bill relating to smoke consumption voted in 1927 by the French Chamber of Deputies deals with a question by no means new, since from 1855 onwards the

Fig. 67. — Adjustable hood on grinder. (Courtesy of the B. F. Sturtevant Company, Hyde Park, Mass., U. S. A.)
Council of Hygiene and Health for the Department of the Seine recommended the feeding of hearths with coke. The Inter-departmental Committee on Carbonisation recently (1927) gave expression to the same recommendation.

Efforts made in recent years for improvement in the methods of stoking are numerous, yet no system which gives entire satisfaction has yet been evolved. Methods for catching smoke before it is dispersed into the atmosphere are not numerous, nor do they represent maximum efficiency in this question.

It should be added that certain industries (pottery, tile and brick making) are carried on under stoking conditions which render methods of smoke consumption almost impossible.

Legislative measures must therefore at the present time be very elastic, making allowances for actual circumstances, and proceeding by way of recommendations and progressive measures of abolition.

The English Act, the efficiency of which is somewhat restricted, is at least possible of application. It excludes "ships, mining and metallurgical enterprises, as well as all industries a list of which may be drawn up by the Minister of Health ". This Act prescribes prevention of production or absorption of smoke "to the fullest possible extent ", and states that a factory emitting smoke may be exempted from any penalty if it is possible to demonstrate that " the best possible preventive measures have been adopted ".

In certain American or English towns there exist organised services entrusted with the application of measures taken in regard to smoke abatement which are worthy of mention. Thus in Liverpool (850,000 inhabitants and a docks population) this service comprises four inspectors; in Sheffield (550,000 inhabitants), six inspectors; in Manchester (760,000 inhabitants), five inspectors. In the last-named town a special committee devotes a large part of its attention to public instruction and the enlightenment of public opinion on the subject.

In Salt Lake City (Utah) the dispersion of smoke is particularly harmful, since bituminous coals, extremely rich in volatile substances (42 per cent.) are consumed in considerable quantities (500,000 tons per annum). In 1919 the State of Utah voted an annual gratuity of $15,000 for the purpose of organising, with co-operation on the part of the town and the Bureau of Mines, an observation centre connected with the municipal telephone system. The factory in default receives, subsequent to a first warning, a visit from an inspector, who studies the plant and applies methods of persuasion, rather than sanctions, with a view to having the required modifications introduced. This method has resulted in a diminution of smoke production amounting to 85 per cent. The Act of 1 November 1920 prohibits emission, for more than one minute per half-hour, of smoke corresponding in density to the No. 3 Ringelmann mesh. Six minutes' latitude is permitted on starting up.

Hygiene *

In the campaign against dust it is often sufficient to effect the dusting process under water (only possible however in certain special circumstances) or to modify sufficiently the material handled to permit of the heavy dust falling to the ground. For this purpose there has been used with satisfactory result oil, water spray, or jets of steam.

Fig. 68. — Dust exhaust hood on surface grinder. (By courtesy of the General Electric Company Lynn, Mass., U.S.A.)

Where technical difficulties render similar methods impossible, the dust produced is evacuated directly in the course of its production. In certain processes involving hand work, however, it is not possible to apply this method. This is the case wherever a large part of the work is done by hand, or where the material manipulated is required to execute various movements of considerable amplitude. In the latter cases, special devices comprising the application of exhaust hoods, to

* According to an original report prepared by the Industrial Health service of the International Labour Office.
prevent the dust being distributed throughout the atmosphere, are necessary.

The installation of an exhaust system constitutes a delicate problem, the solution of which varies according to the peculiar circumstances of each case. It may even be said that for every type of process or raw material a different variety of application of the same principle is required.

There should be mentioned the operations of crushing, grinding, sieving, mixing, bagging and barrelling, as well as transporting, decanting, etc.—operations for each of which technical progress has resulted in the provision of a suitable apparatus for rate of flow, and situation of the ventilator, air speed and depression, dust recovery.

In certain cases it suffices to cover the machine during the production of dust, and to create a moderate depression in the interior; the cover should naturally be as airtight as possible, and the only openings required permanently will be those used for charging and discharging the machine when the latter operations are continuous, for should joints allow the air to pass towards the machine, the depression caused inside the machine becomes reduced.

The dust which is not withdrawn into the exhaust duct is raised by dust exhaust at the very point at which the dust is given off, together with withdrawal of the dust as it is produced. Besides installing localised ventilation, there must of course be provided a general system of ventilation for the workroom, as well as measures for personal protection (skin, respiratory organs, eyes, etc.). Exhaust by downward or upward draught is applied, according to the nature of the dust, by means of air ducts situated on the ceiling or under the floor, or at times by means of a mixed system.

The solution of the problem must take account of several different elements: means of catching the dust, plans and section of the piping, type, the air currents, and it suffices to open the cover at certain well-chosen points in order to collect it from time to time.

In other cases the covering of the machine can only be partial, and the exhaust ducts then require to be installed as near as possible to the points at which dust is raised. The system varies according to the type of dust in question; thus, for example, where inert dust is concerned, pressure requires to be exercised, whilst in the case of active dust projected at a certain speed by rapidly revolving machinery, the motive force of this will project it into the exhaust ducts without the mouths of the latter being

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**Fig. 62.** Cyclone separator for catching coarse particles, chips, sawdust, small stones, etc. (By courtesy of the B.F. Sturtevant Company, Hyde Park, Mass., U.S.A.)
necessarily placed at the point of formation, as is the case with inert dust. In other cases, the problem has to be met by a uniform and effective exhaust system throughout to overcome the speed of the dust created by quickly revolving machinery.

The exhaust installation should be so planned that the workers are not inconvenienced by the presence of draughts. The mouth of the apparatus should be small for localised dust production. It should have the form of a funnel, or a box form, the dimensions and form naturally varying in accordance with the machine which it is required to serve. Sometimes the mouthpieces are fixed on flexible tubes, so that the worker may withdraw or approach them, as circumstances require. They may also be furnished with a machine to exclude unduly large fragments.

Certain processes (rag and wool sorting, etc.) require the use of an exhaust lattice (downward draught). As regards the ventilation piping, it is naturally preferable that provision should be made for its installation when the factory is first constructed. It is advisable then to construct the pipes of masonry, and to have them fixed to the walls or the ceiling (on the upper floor). The inner wall of the piping should be smooth and circular in section, to prevent all accumulation of dust likely to lead to the choking of the section and consequently to a reduction in its capacity. Supplementary pieces and elbow-joints should never be right-angled or abrupt, with a view to avoiding all loss of capacity arising from whirling of the dust, and consequent choking of the apparatus.

The diameter of the collecting duct should increase from its extremity up to the point where it meets the last branch of the primary piping. The vertical section of the central piping should at any point be equal to the sum of the vertical sections of the primary piping which it has met with up to this point. The velocity of the air would then be about the same in all the pipes. In order to economise the power, it is necessary to provide each branch pipe with a regulator, which can be opened or closed as desired. It is further necessary to arrange orifices for cleaning apparatus at points where the dust tends to collect.

All things being equal, for a good exhaust system the diameter of the pipe will vary according to the type of ventilator used. As regards the plant in general, there may be used a special system for each machine, with mouthpiece, piping and ventilator, or in the case of large scale establishments, a general plant with central ventilator. Each machine is then furnished with a regulating device required for regulating the ventilation. Where it is a question of machines with varying speeds...
of withdrawal, or with long and complicated contours, it is preferable to install small groups of similar machines, each attached to a separate ventilator.

The velocity of the air current depends upon the kind of work done by the machine served. Whilst a strong draught will not constitute a disadvantage in the case of planing machines, and whilst it is of advantage for catching the particles given off from a grindstone, this is by no means the case where the materials being handled are tenuous and flexible and must follow a given course. It may be said in general that for light types of dust (and for gas) a speed of 0.50 to 1 m/sec. will suffice; for heavy dusts a speed of 1 to 4 m/sec., and direction of the air current and in its velocity, but whatever may be the length of the piping, its depression and its velocity, in order to provide effective withdrawal, must be read at the branch piping situated at the greatest distance from the ventilator.

At a short distance from the mouth-piece of the exhaust tube, the above velocities only give a depression of from 1 to 2 mm. of water, corresponding to quite a low rate, which cannot in consequence cause inconvenience to the workers.

The ventilators used are of the helicoidal type (air displacement) or centrifugal (at high pressure) or transversal, or finally, revolving ventilators (water pump, eccentric pump). As regards the best type in any particular case, it must be said that the helicoidal ventilator is essentially an apparatus for general ventilation, utilised in particular cases where it is a question of very light dust to be captured in piping of large volume. In general, centrifugal, transversal or revolving ventilators are used, where it is a case of circulating air in long pipes (high pressure).

The choice of a ventilating system depends entirely on the objects in view. Thus, for instance, where it is necessary to remove by exhaust obstructing waste, the arms of the ventilator should be arranged in such a fashion as to avoid intercepting the passage of such waste.

The air coming from the exhaust

![Diagram](https://example.com/diagram.png)

**Fig. 71.** Pneumatic conveyor for handling finely divided powdered materials. See also fig. 70. (By courtesy of the Dust Recovering and Conveying Company, Cleveland, Ohio, U.S.A.)

where there are small particles in the products aspirated, a speed rising to 30 m/sec. may be necessary; for dust from textile materials there is quoted a rate of 10 to 15 m/sec.; for cement, coal, and air dusts, one of 15 to 18 m/sec.; for sawdust, 10 m/sec.; for dry wood shavings 15 to 18 m/sec.; and for damp wood 20 to 25 m/sec. It is, however, poor economy to aspirate the air in a duct at a rate exceeding 20 m/sec., since the resistance, and in consequence the loss of capacity, increases in proportion to the square of the speed, and the force expended proportionally to the cube of the speed. Resistances are due to the roughness of the interior walls, to their extent, and to the abrupt changes in the
pipe is subjected to dust removal, an important operation engaged in with a view to recuperating products of value (precious metals, potassium, cement) or to preventing the deposit of dusts in the neighbourhood of the factory, or finally, with a view to cleansing the air prior to circulating it a second time in the workrooms in order to economise heating expenses necessitated by constant provision of fresh air.

The precipitation of dusts may be effected by: (a) abrupt decrease of the velocity of the air current by making it pass through chambers adapted to this purpose (collecting by relaxing air tension); (b) sudden change in the direction of the air by intercepting the air current with baffle plates arranged "checker-wise"; (c) precipitation by water; (d) separation by centrifugal force; (e) retention of the particles on rough interior walls or filters; (f) precipitation in the electric field.

In dust chambers the velocity of the air currents should be reduced to 0.3 to 0.6 m/sec. These dust chambers must therefore be very large, which is often a disadvantage. Further, such chambers are often emptied by shovelling, and the occupational hygiene problem in consequence receives but a very imperfect solution.

The same remarks are applicable to "baffle chambers". The surface of the baffle plates is sometimes covered with a kind of flannel or plush kept damp by a spraying of water. Efficiency of the apparatus is in this way increased, and it is by this means possible to capture 90 per cent. of the dusts.

Precipitation by water is effected in chambers or towers in which air meets with sprays of finely pulverised water coming from special twayers or dampers. A plant of this kind requires to be supplemented by tanks for decantation of the mud. A simpler system consists in blowing the air given off by the ventilator into a ditch filled with water.

Apparatus depending on centrifugal force is often employed for coarse dusts, sawdust and wood shavings. The most commonly used are "cyclones", consisting of a sort of large cast-iron funnel in which the air passes tangentially through the upper part, assuming a whirling movement. In consequence of friction against the walls and diminution in the velocity, the dusts fall into the lower part, whence they are evacuated by opening the damper. The air, freed from dust, is emitted from the upper part of the apparatus by a large tube. The cyclone machine only retains very large particles, the finely divided particles, especially of wood, are withdrawn by ventilation. For this reason, the ordinary cyclone separator has been perfected by the adoption in the interior of the apparatus of a rectangular and helicoidal pipe, which serves as a better guide for the gases.
for the air, which is thus forced to pass again below the air current supplied. Further, the upper opening of the cyclone is furnished with a system of arms the flat blades of which cause the air withdrawn by a whirling movement to resume gradually its normal direction. The velocity is transformed into pressure, thus augmenting the power (Prandtl). Centrifugal force is equally utilised in the Lump exhaust collector. This consists of a revolving exhaust on the axis of which is adjusted the collector, a cylindrical drum into which the dust-charged air is driven back. In consequence of the revolving movement of the drum, the dust is projected against the interior wall by the centrifugal force and there main-

The air to be purified is brought into sharp contact with the surface of water contained in a tank, thus precipitating the greater part of the dust. The final particles are removed during passage through a layer of coke placed in the upper part of the tank and supported by a metal trellis. For the filtration of dusts, bag filters of very fine material which is not air-tight, are mostly used. These bags are suspended upside down in a large chamber constructed of wood or cast-iron and divided into compartments each containing four or eight sacks. A ventilating apparatus causes a depression in the chamber. The dust-charged

![Diagram of Sack-Type Filter with Automatic Cleaner](image)


dust which is deposited quickly chokes up the pores of this filtering material which have to be shaken from time to time. Shaking is done by hand or mechanically. In the latter case the sacks are hung on to a lever with a spring which keeps them stretched out during ordinary functioning, while a cam closes the dust trap. For shaking, this cam is made to act bringing the lever into motion and producing a shaking movement of the sacks, at the
same time a displacement of the cam causes the trap which communicates with the outside to open and the chamber being under depression there is an entry of air which favours the fall and passage of the dust into an evacuating hopper. The division of the chamber into compartments allows a certain number of the filters to remain in action whilst the others are being shaken.

Where it is a question of heated gas which might burn the material of which the filters are made, it must first be cooled by passage through special chambers. In the case of highly inflammable dusts, asbestos filters or filters made of fireproof material are used.

The filtering sacks are sometimes situated at the end of the exhaust duct and thus receive slightly compressed air instead of being subjected to aspiration. The filters are no longer required to be placed in a special chamber, the filtered air being dispersed directly into the workroom. This device is employed in the cement industry for laying dust raised during the operation of storing in silos or during bagging.

Certain filter systems are simply composed of felt frames or of boxes lined with sand, asbestos, coke, etc. Metallic filters which are resistant and require little maintenance are becoming more widely used industrially. In principle they consist of two metallic grids or lattices stretched on parallel frames between which are situated a heap of small rings (Raschig rings), plates, grids, etc., also made of metal. According to the purpose for which they are used the parts of these filters are coated with zinc or lead. In order that the dust may adhere to them more completely, they are watered or impregnated with special oils to which antiseptic substances are added when the air liberated must be entirely freed from germs (food industries, production of serums and ferments).

Other models of metallic filters are finally composed of a lattice or chain of small plates in the form of an endless band. A system of rollers imparts action to the filter and causes it to pass through a bath of water into which the dust is discharged.

These types of filters are suitable for large establishments: blast furnaces, gas generators, etc.

A recent type of dust remover operates in two stages: the first part of the
apparatus recuperates the greater part of the dusts by a dry method; in the second part the gases are freed from residual particles by a wet method. The combination of these two methods renders the apparatus of maximum efficiency.

The diversity of the systems used for dust removal demonstrates that the problem is still far from solution. Fault may be found with the systems above referred to on account of the constant attention and maintenance which they demand, the fairly considerable resistance which they frequently offer to currents of air and gas, the obstruction which they cause, and especially the fact that they permit of the passage of the finest qualities of dust, which are precisely the most dangerous.

There will now be mentioned briefly the various causes which render a dust exhaust system less efficient or inefficient.

Sometimes the mouthpieces of the exhaust ducts are too small and the dust thus escapes or their form may be defective and involve accumulation of dust, or, finally, the orifice so small that it eventually becomes choked with dust. Wrongly calculated ventilation or defective maintenance favours reduced speed of the air current in the piping, and the power of the machine is merely used to overcome a useless resistance. The angles of the branch piping may retard the air current, permitting of an accumulation of dust and favouring obstruction of the pipes.

It is not necessary to insist further on other defects of construction such as mouthpieces detached from the piping, escapes and holes in the interior walls, accumulation of debris choking the pipes, etc. What is certain is that an effective installation can only be planned and constructed by a trained and competent expert, for the problem in question is a very difficult and delicate one. On the other hand, careful maintenance is equally necessary for assuring consistently good results.

An improvement has certainly been obtained by the method of electric precipitation of dusts. It is known that flocculation of aerosols is obtained by displacement of the gaseous envelope which covers them or by provoking a variation in the electric charge which protects the particles. By mixing with an electrified aerosol another dispersed substance charged with electricity of an opposite sign, a similar effect is obtained to that produced when the first aerosol is composed of neutral particles. The latter by induction become charged with electric particles containing electricity with an opposite sign, thus producing attraction. The principle of electric precipitation of smoke discovered by Lodge in 1884 was industrialised by Cottrell in 1906. If smoke is subjected to an electric charge at high tension by which the molecules of the suspending medium (air) become charged, those of the suspended medium (solid or liquid particles) charge themselves by absorption of gaseous ions.

![Separator Chamber, Cottrell Process](By Lurgi-Apparatebau-G.m.b. H., Frankfort-on-M.)

1. Collector electrodes (earthed).
2. High-tension electrodes (wires).
4. Impure gas.
5. Dust.

These particles then unite under the influence of the electric field forming threadlike aggregates arranged along the lines of force of this field, and these aggregates soon become deposited on the floor of the workroom in which the process is being carried out.

A Cottrell unit consists of a vertical metallic conductor at very high tension,
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usually having a negative charge, and surrounded by a vertical metallic tube of which it constitutes the axis, the latter being earthed. The intensity of the electric field thus produced between the wire and the tube causes intense ionisation of the atmosphere passing through the tube, and the negatively charged ions of the gas travel at very high speeds from the wire towards the tube. These ions are absorbed by any dusty particles present in the air, thus acquiring a charge of electricity of the same sign, which causes them to be attracted towards the tube where they discharge and agglomerate, finally meeting in the lower collector.

When the dust consists of several dispersed constituent parts, with different degrees of volatility, it is even possible to profit by the fact in order to obtain separate precipitation.

These principles have been applied industrially by grouping sheaths of vertical tubes similar to the unit described above or by erecting vertical wires at high tension in rooms constructed of masonry in parallel planes separated by parallel metallic sheets disposed vertically and connected to earth.

Whilst this method has been very widely applied in the chemical and metallurgical industries, it must be admitted that the expense of installing it and running it is usually too high to permit of its adoption in order to recuperate dusts which have no commercial value, the elimination of which would, however, be of interest from a health point of view (granite dust or other rock dust, for instance). However that may be, a large extensive field of application awaits this method in the sphere of industrial hygiene.

The literature of metallurgical and chemical trades provides ample descriptions and bibliography in reference to this subject, which it is not necessary to reproduce here.

Certain other considerations are worthy of attention. Thus, for example, in countries with a severe climate, it would be, especially in winter, unduly extravagant to drive the dusty air outside when the workrooms require heating. The heated air thus withdrawn by ventilation must be replaced, otherwise the temperature will tend to become uncomfortably low. This heat loss can be avoided by filtering the dusty air and recirculating it either partially or in its entirety. When the air has been contaminated by toxic gases (for instance, carbon monoxide) which cannot be eliminated by filtration, re-circulation is impractical, under these conditions, there is no economical substitute for withdrawal by exhaust of the filtered air and its rejection outside.

The increasing use of small pneumatic tools, in the granite-cutting industry, for instance, involves a very important dust risk. For this reason it is necessary to provide, close to the working post, localised systems of exhaust so designed that they do not interfere with the worker.

The use in rock boring of pneumatic boring machines revolving at high speed gives rise to a great quantity of dust, and an effort to reduce the [

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**FIG. 77.** — Size-frequencies of dust particles in dust mask tests, 250 particles measured for each curve. The filtered dust gives smaller and more uniform particles than the unfiltered. (See also fig. 63.)

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danger therefrom is made by furnishing rock drills with a jet of water sent through the centre of the drill, which helps to allay the dust. This system possesses the further advantage of cooling the borer and of clearing the holes which have become stopped up as the points of the instrument advance into the rock. When drilling is done overhead or when the mine is situated at a depth at which the temperature of the rock constitutes a serious objection to the presence of excessive water, wet boring is unpopular and recourse must be had to another method in the pursuit of the anti-dust campaign. For this reason
use has been made of the air escaping from the pneumatic borer for withdrawal of the dust by suction. This method, however, has not been sufficiently applied in mines to convince mining experts that the apparatus in question is compatible with working efficiency. Compressed air lines running to the working faces and "dead ends" are often utilised in mines with a view to diminishing the dust concentration and refreshing the workers.

Reference is made in the article "Gases and Fumes" to the best means of capturing these and removing them from the workroom. Similarly, the principles which are at the basis of the anti-smoke campaign have already been briefly referred to above. The use of pulverised coal has, at the present time, raised a new problem of pollution since the smoke generated by this method of stoking has a total and carbon content higher than that produced by other industrial systems. Since furnaces fed by pulverised coal appear to be thermally more efficient than stoker-fired furnaces their utilisation will in all probability continue, and it is therefore necessary to discover economical methods capable of combating the pollution of the atmosphere.

In order to purify the air of large establishments (theatres, restaurants, libraries, museums, public halls, etc.) use is sometimes made of viscous filters, air washers and sack filters, particulars of which do not require to be given here. It suffices to say merely that where air washers are used these devices are of but little value from the point of view of industrial hygiene, since water forms a comparatively poor dust catcher.

In regard to personal protection by means of masks, the reader is referred to the article "Respiratory Apparatus". It should, however, be recalled here that experience during the war has clearly demonstrated the efficacy of gas masks against the action of small quantities of any kind of gas no matter how toxic, and has also demonstrated that the wearing of such masks is distressing and uncomfortable where it is protracted for a considerable time. Objections have been made by those obliged to wear them; and it is therefore only in the case of serious danger or where a very severe discipline is applied that they are accepted. Their peace-time industrial application for emergency use is, nevertheless, extensive. These masks may be used in fact for all kinds of gas, provided the concentration is inferior to about 3 per cent. The problem becomes more difficult of solution when it is required to construct masks or respiratory apparatus for protection against particulate matter. In fact, where the gas molecules are continually activated by violent kinetic motion, the dust molecule, if in a state of very fine subdivision, only presents a Brownian motion which is insignificant compared with the motion of gas molecules. It is for this reason that chemical absorbents are not utilised in anti-dust masks. The fibrous materials, such as cotton, pulp, wool, etc., are only effective for catching fine particles in suspension. They, however, present certain well-known advantages. Fig. 77 shows that the masks which are effective against dust only permit the passage of small particles which, though important from a health point of view, do not traverse the mask in sufficient quantity to be harmful.

**Medical Examination**

In view of the present ignorance of threshold or permissible doses for most of the common dusts and fumes, there is no substitute for the periodic medical examination as a precautionary measure. Even in the South African gold mines, where dust concentrations are regulated by law, periodic examinations are considered indispensable. It should be remembered that it is the medical findings, after all, which really evaluate the dust hazard.

Compensation for industrial diseases probably has more effect than any other single factor in removing the cause of the disease. Whether compensation is enjoined by law, as in most parts of the British Empire, or whether responsibility is assumed by the employer through group insurance, as often occurs in the United States, the beneficial effect is evident. Compensation is particularly important for diseases like silicosis, because the dust which does the damage has no value and its recovery or prevention is of no economic interest.

**Legislation**

In general, legislative measures exclude children, young persons and women from all work involving exposure to dust, whether it be toxic or not, where precautions are not taken with a view to preventing liberation of dust. It is not possible to enumerate here the list of industrial operations or of products
liberating dust from which legislative provisions exclude women and children. Reference should be made for this to the various articles of the Encyclopaedia, and particularly to the articles entitled "Industrial Hygiene (Workshops)."

It should, however, be mentioned that in the United States certain States exclude young persons under sixteen years of age from all operations where dust is liberated in harmful quantities (Alabama, Arkansas, California, Kentucky, Maryland, Wisconsin, etc.), from operations in which toxic substances liberating dust are handled, and from all industries in which mineral, vegetable or animal dust is liberated in harmful quantities, including silicious dust, dust from clay, talk, tobacco, caoutchouc and mineral dust (New Jersey, etc.). Injuries due to toxic dust are subject to compensation in the State of Illinois.

Ulcerations of the skin, of the mucous membrane of the nose and mouth due to toxic dust and liquid, are subject to compensation in Great Britain, excematomul ulceration due to dust in Western Australia, and conjunctivitis due to dust in Japan; and ulceration of the mucous membrane of the nose and mouth is subject to compulsory notification in the Netherlands. (See also articles "Occupational Diseases: Respiratory Apparatus" and "Occupational Diseases: Compensation," and "Tuberculosis and Silicosis").

**BIBLIOGRAPHY**


The plates for figs. 59-65 and 77 have been kindly lent by the proprietors of the Journal of Industrial Hygiene, Boston, U.S.A.

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**Dyeing**


**TECHNICAL DATA**

Dyeing consists in fixing on textile fibres (thread and material) colouring matters with stable colours which resist washing and the decolourising action of the atmosphere and of light. The colours which satisfy these conditions are known as fast dyes (see article "Dyes").
The dyeing processes commonly followed are of two classes, immersion of printing.

1. In "dyeing by immersion" the textile fibres are brought to a uniform colour by being thoroughly impregnated with the colouring medium. The technique applied for this purpose comprises the following operations:

(a) Bleaching and scouring in order to remove from the fibres foreign matter adhering to the surface and to remove all colour and clean them (see article "Bleaching").

(b) Mordanting, which is necessary in the use of certain colouring mediums, has for its object the fixing in the fibres to be dyed of "mordants" consisting of various chemical agents acting as an intermediary between the material and the colouring matter and assuring fixation of the latter on the textile fabric.

(c) Whether mordanted or not, the fibres are subsequently passed through one or more baths of dye as occasion demands. The dyeing operation is usually preceded by a preliminary treatment with a suitable preparation (cold water, hot water, suitable solvents, acids, alcohols, colouring matter in powder form or in liquid extracts of a sticky consistency, etc.). They are used at varying temperatures as occasion demands, the heating required being often provided indirectly (steam circulated in pipes encased within the sides of the vats). The fibres are then passed through various baths by hand or by the use of small sticks or by more or less complicated machinery providing thorough stirring.

(d) Cleaning of the dyed material in order to free the stuff from traces of the dye bath by passing it through a current of cold water either by hand or with the aid of certain machines (rippling machines, washing machines).

(e) Wringing or drying by hydro-extractor, with a view to eliminating the excess water present in the material. At this stage certain colours are sometimes brightened, developed or even converted into other shades by certain supplementary operations (treating by steam, steeping, action of baths of soap and hot water or chemical baths, etc.).

(f) Drying in the open air or better still in drying chambers furnished with hot air or steam or in special machines (drying-machines or spreading on drying-frames).

2. In "dyeing by printing" the fibres are dyed superficially by mechanical application of one or several different colours on one side, or at times both sides, of the material, applied in such a way as to impart regular and artistic designs to the material. This industry, which is of ever-increasing importance, has assumed a very extensive development (batik).

The application of the requisite substances (colours, mordants, discharges, etc.) is done by hand by the use of a block or large brush, or by mechanical processes (Perrot's press) or by entirely automatic processes (cylinders, surface looms) — processes all based on the use of relief or hollow engraving, of which there may be intermittent (resembling hand printing, as in the case, for example, of batik materials) or continuous (mechanical) processes.

Amongst the numerous technical methods employed, the processes of direct application (simple application, solid application) are less used than the fixation process (application of a colouring powder fixed in varnish, adhesive matter, glue, alumina, casein, gluten) and are certainly less frequently used than the mordanting and dyeing process by which mordants are printed on certain parts of the material, which are thereafter dipped into colour vats. The use of mixtures of colouring agents with mordants is becoming increasingly resorted to, the material thereafter being submitted to steam treatment (steam dyeing). A variation of this process is printing by the use of a reserve in which the colours are uniformly fixed, except on certain parts having received prior treatment with a suitable preparation (reserve or resisting agent). In these processes, after fixing the mordants and the reserves, the materials pass for drying into heated chambers (drying and oxidation chambers) in which a current of hot and humid air circulates. The excess products (mordants, reserves, thickening agents and colouring substances) are removed by passing the materials through hot baths, the composition of which is varied according to the operation in question (degumming and dung removing) by cleansing in cold water and rinsing. Dyeing is then effected in the usual manner.

Printing by abstracting or by the use of discharges is founded on the application of chemical agents which cause the original white of the material to reappear against the background of colour imparted or replace it by a different colour.

The removal of stains and cleaning of garments and worn materials may constitute, apart from the preliminary operation in dyeing, a separate industry of a certain importance. These operations are effected by two processes used to complete each other, and both of which are mostly necessary to give good results: cleaning (removal of grease spots) and decolorising, which consists of elimination of matters only present in traces but visible by reason of their colour.

Cleaning of scalded substances is effected by various methods:

1. Dissolving in appropriate volatile solvents (see article "Solvents").

2. Action of emulsifying agents which transform the dirt present into extremely fine droplets, which become disseminated in the cleaning liquid (soaps, soap solutions, ox gall, alkalis — potassium, soda, ammonia).

3. Absorption by contact with powders or porous materials (plasters, Fuller's earth, tapioca, kaolin).
4. Superficial destruction of the soiling material either by rubbing with an abrasive or by decomposing the stains by a suitable reagent which renders them invisible or soluble by treatment in certain baths.

Removal of stains consists in partial cleaning by which one or several stains are removed after brushing and beating of the material, by rubbing each stain with a brush impregnated with a suitable solvent and by taking great care to remove these stains rapidly in order to avoid the formation of maps. Complete cleaning is effected by means of the following processes:

1. In cleaning in a wet state, also known as steam cleaning, materials manipulated by hand or more generally in special apparatus, fulling mills and washing machines, are cleaned with soap and a brush and then dipped into a soapy bath, which operation is repeated a second time, and finally they are dipped into a bath of caustic soda or being treated several times in hot and cold water, the materials finally pass into acid baths (acetic hydrochloric or sulphuric acids) or into alkaline baths, as the case may be (ammonia), with a view to brightening the colours. They are then partly dried in hydro-extractors on heated cylinders or by means of steam. Then they are thereupon freed from excess water in hydro-extractors on steam-heated rollers, and finally dried.

2. In dry cleaning, utilised specially for delicate colours (checks, stripes, light grounds, printed materials), suitable solvents are used into which the materials are dipped, then pressed or squeezed as in the foregoing processes. These operations are really effected in fulling mills, but more often in revolving cylinders which enable the work to be done rapidly and evenly. The materials are then passed through hydro-extractors, dried in the open air or in hot-air drying chambers. Perfected machinery enabling all the operations to be effected in closed apparatus which delivers the materials completely cleaned, and at the same time effects recuperation of the solvents employed, is being more and more widely used, especially in large establishments.

Ironing by irons or by special machinery — steam tables, etc. — calendering, imparting of a watered or moire appearance often complete the operations of cleaning. Mention should be made of the operations of degumming and degreasing with lubrificating oils, which is effected with the aid of suitable solvents or by the action of steam which removes the fatty substances. These operations, carried out by special machinery in large railway engineering works, make it possible to recover almost all the lubricating oil in question.

**SOURCES OF RISK**

In the course of the various operations referred to, the sources of risk classed as follows:

1. The temperature of the workshop constitutes the principal risk represented by time spent in a hot and humid atmosphere. In the workrooms in question the temperature registers 35° to 40° C., which during certain operations (degumming, removal of dung) may even rise to 50° C. The harmful action of this heat is increased by the humidity rate due to clouds of steam given off by the different baths. Mention should also be made of the exposure of the workers to sudden changes of temperature and to draughts.

2. The standing position for a prolonged period necessitated by certain operations.

3. Contact with harmful or toxic products. Whilst in the dyeing industry the use of toxic colouring agents has greatly diminished — alizarin colours are not very dangerous, and lead and arsenic colours are now very little used — it is nevertheless the case that mordants and fixing agents fairly often employed may be the cause of injury, and that in dry cleaning at least toxic solvents are utilised. Amongst other toxic or irritant fumes mention should be made of fumes of hydrocyanic acid (given off in the course of dyeing and printing operations, as well as Prussian blue or Paris blue — secondary reactions from cyanated products used), chlorine fumes, sulphur dioxide (given off during bleaching), acetic acid (given off by the mordants), hydrochloric acid (liberated during printing by steam), pyrroligous acids, ammonia (given off during indigo printing), etc.

Continual contact with the liquids used as reagents or alterants (acids, alkalis, salts, oxides or reducing products) constitutes a source of risk which is all the more important in course of the preparation and utilisation of mordanting and dyeing baths, since the solutions used are generally contained in vats placed upon the ground, so that the workers frequently receive splashes from them and become soaked with the liquids. Thickening of mordants and colours (arsenic greens) gives rise to similar risks, especially when the thickened mixture has to be spread on the material by means of a brush or by hand (dyeing by printing).

Mention should also be made of bleaching agents (sulphuric acid, soda and lime ies, chloride of soda and of lime) and these are of greater importance by reason of the fact that they are often used as a means of removing from the skin, hands and arms
especially, stains received in the course of work.

Amongst the solvents, mordants and discharges used may be quoted the following: acetice acid, nitric acid, sulphates of alumina and potassium and soda aluminates. A dangerous operation is the impregnating of silk threads with acetate of lead prior to dyeing.

As regards colours, reference should be made to the article "Dyes". Drying by hydro-extractor is one of the most dangerous operations, since pulverised particles are disseminated in all directions. It is necessary further to mention the dust given off in course of the preliminary operations, especially that liberated by used garments or material, certain of which might contain more or less important traces of lead, arsenic, etc.

STATISTICS

The available statistics relative to dye workers are few in number and not at all recent. For this reason it has been thought preferable to confine mention to the most recent mortality statistics furnished in England and covering the period 1921-1923. These show that amongst workers in the dyeing industry mortality is well above the average standard mortality for the general population of all ages. This high rate, however, does not affect one large group more specially than any other. The data in question would indicate a general state of defective health rather than the effect of a special occupational risk.

PATHOLOGY

According to observations made some time back by Layet, the most widespread troubles met with are diseases arising from cold; various forms of rheumatism, chronic catarrhal affections of the bronchial tubes, chronic coryza, etc.

In connection with the digestive system, there have been noted lesions on the lips and gums, due to the action of irritating fumes, catarrh of the digestive organs (gastro and intestinal dyspepsia), which were found to be highly frequent amongst old workers (Layet). These last troubles are chiefly brought about by the effect of exposure to a damp environment, by perspiration and by draughts, but may in addition be favoured in their development by the action of certain irritant dusts and certain fumes. In this way Layet attributes to alteration of the buccal secretions as a result of the influence of irritant fumes the majority of derangements of gastric secretion.

As regards local effects, the most outstanding are conjunctivitis and especially dermatitis.

Numerous cases of eye disease were reported about twenty years ago amongst workers in the dyeing industry. Harmful products responsible for these were chrome salts, alkalis and aniline colours. Forms of conjunctivitis characterised by a special colouring of the mucus of the part of the eye unprotected by the eyelids have been met with. Where aniline colours had been used there was also encountered photophobia and mydriasis.

In 1897 Senn reported among 35 dye-workers 18 cases of a blackish-brown coloration of the conjunctiva covering part of the eye unprotected by the eyelids; 8 of these cases showed also a brown coloration of the cornea. The workers in question were over forty years of age and had for long been engaged in the factory. Senn attributed these lesions to the action of hot fumes from the vats and especially to those of quinones (see article "Dyes").

As regards dermatitis, apart from the coloration of the skin (due to the dye-baths), there had been reported the occurrence of eruptions, ulcerations, cracks, eczema and excoriations situated especially on the hands and forearms, due to the local action of the solutions and preparations utilised. The epidermis of the hands, continually immersed in the dye-baths, degenerates, becomes altered and thin. The superficial layers of the skin become irritated and extremely sensible with the appearance, especially on the lateral surfaces of the arm, of small blisters which break, leaving exposed papillae surrounded by a ring-shaped crust. Contact with the irritating products then leads to ulceration, the morphology of which is dependent on the products in question (Layet). There should be mentioned in this connection the occurrence of hyperhydrosis, abscesses and carbuncles, which may be caused by chloride of lime.

The lesions occasionally assume the aspect of occupational stigmata: amongst fullers engaged in cleaning cloth the epidermis of the hands become blanched, wrinkled, raised in places, especially on the corresponding surfaces of the thumb and first finger between which the pieces of cloth are held for unrolling (Tardieu). Continual contact with acids or alkalis
brings about in the long run derange-
menis of the circulation and of the
sense of touch of the hands (heaviness
and anesthesia). Atonic ulcers of the
lower limbs are not rare, nor is cramp
of the calves of the legs and trembling
of the legs, met with by Layet amongst
numerous workers. These he attri-
tutes to fatigue, to constant standing
and to the action of humidity.

General poisoning may at times
occur as a result of contact with harm-
ful products. There should likewise
be recalled the possibility of catching
infectious diseases, especially during the
operations of removing stains and
cleaning clothes or cloth which has been
in use, contamination being
brought about during manipulation of
these (action of dust). These risks are
all the more marked where adequate
sanitary accommodation is lacking.

Such is the occupational symptom-
atology as described by Layet. At the
present time, however, thanks to
general or personal measures of hy-
giene, made possible of application
owing to recent technical improvements,
occupational injury is much less
frequent in the dyeing industry, which
is in consequence distinctly less
unhealthy than formerly.

It should be noted in passing that
where clouds of steam are thick and
heavy they interfere with the sight and
in consequence may increase the risk of
accident. Steam from very hot baths
exposes workers to the risk of burns.
Damp and slippery flooring may bring
about falls amongst workers moving
about in the workroom, falls which
may result in very serious con-
sequences because of proximity to vats
and heated machinery. It is necessary
also to take into account the action of
certain intermediary products as well
as impurities in the substances utilised
(in particular, cyanated compounds
and rhodanates). The fumes given off
by vats of colouring solutions contain-
ing aniline black have been known to
cause cases of keratitis (Schuler, 1898-
1899). Russian doctors have made con-
ditions in dye-works the object of
special research. Hellmann (1938)
studied during two years the pathology
of workers engaged in dyeing and
found cases of dermatitis, 8 of which
occurred amongst workers using dyazo-
basic and sulphur colours. In the
majority of operations in question hot
lyes were manipulated. The outbreak
of dermatitis had been caused during
a period of acceleration of the work,
which had resulted in the workers
omitting certain measures of precau-
tion (use of gloves, etc.).

Rosenbaum (1928) sought to determine
the dynamic relation between meteor-
ological factors and work by studying
conditions of work in a dye factory for
dyeing textile fabrics. Letawet and
Feinberg have likewise investigated the
influence of meteorological conditions
on the health conditions of dye-workers.
Their observations lasted over a whole
year and covered 92 women employed
in two factories. The period under
observation comprised 520 working days
in a single workshop and affected work
done in a standing position.

The influence of meteorological con-
ditions made itself felt to a considerable
extent on the body temperature, for the
latter rose parallel to the effective
temperature of the surrounding atmos-
phere. The influence on women was
more distinctly discernible than that
on men, and again more so on new
workers than on those accustomed to
the work in question. Good adapta-
bility of the constitution to high tem-
peratures in the case of easy work has
been met with in an atmosphere show-
ing a temperature of from 23 to 28° C.
The breathing rate was shown to
depend more on the meteorological
conditions than on other factors of
muscular work which accelerate the
breathing rate. Reciprocally, muscular
work had a greater influence on the
pulse rate than the meteorological con-
ditions.

A contribution to the study of the
effects of steam in dye-works, interest-
ing from the point of view of industrial
hygiene, is that of Heim de Balsac
(1908 ?). Part of this study deals with
the chemical composition of the clouds
of steam and with the question as to
whether it exerts an influence on hy-
giene in the workshops in question.
The research carried out by the above
authority was in connection with the
dyeing process effected by dipping in
hot solutions followed notably by
dyeing in an acid bath, of wool, silk,
and mixed materials. After having
analysed the composition of the baths
utilised at this period in two important
dye-works independently of formulae
given in treatises on the subject, he
made use also of the very complete
table drawn up in accordance with his
request by the director of the dyeing
company, as well as in accordance
with information furnished by a chemi-
ical expert engaged in the dyeing
industry.

Without going into detail in regard
to certain variations between the con-
ditions found and those existing at the
present time, it suffices to remark that
the experiments made by Dr. Heim de
Balzac led him to the conclusion that samples of air saturated with steam; taken above the dyeing vats, contained a maximum of 1 to 2 mg. of sulphuric or acetic acid per cubic metre, less than 1 mg. of sulphate of soda and less than 1/4 mg. of colouring matter. By taking the average figure of eighteen inspirations a minute and that of a half-litre of air inhaled at each inspiration, during twelve working hours in an atmosphere saturated with steam given off by dyeing vats the worker would inhale at the maximum 12.96 mg. of acid fumes diluted in 6.48 cubic metres of air, 6.8 mg. of sulphate of soda and 9.07 mg. of colouring matter. It is therefore not possible to attribute a harmful role to these quantities of chemical substances contained in the steam formed above the dye-vats.

The same authority claims that the use of sodium sulphate in the dye baths is of no special interest from the point of view of industrial hygiene, since the traces of sulphuretted hydrogen liberated in the atmosphere were too slight for estimation. He had no personal experience in regard to dyeing with aniline black.

It has also been stated that the mordanting baths in the dyeing of turkey red were liable to give off steam containing chemical products responsible for injuries of a general kind, reported by the French Factory Inspection Department (1904). No research has, however, been effected in order to provide a confirmation of this statement.

In the annual report of the Chief Medical Inspector of Factories in England there is a very interesting information in regard to the occupational risks to which workers in the dyeing industry are exposed. Since 1925 the attention of factory inspectors has been devoted to cases of dermatitis, caused chiefly by the use of irritating substances (alkalis) for cleaning the hands. It is, however, somewhat difficult to distinguish between the cases of dermatitis affecting dye-workers and those affecting workers in the chemical industry. However that may be for the group designated as "dye-workers", the following rule per cent. for dermatitis was reported: 1925, 12.5; 1926, 7.1; 1927, 8.8; 1928, 7.5. The number of cases of lesions of the skin due to chromates was in accordance with cases notified as follows: 1920, 43 cases; 1924, 18; 1925, 52; 1926, 39; 1927, 25; 1928, 28. For particulars relating to aniline black, see article "Aniline".

Hygiene

The dyeing establishments are classified under the heading of dangerous trades (gases, abundant clouds of steam, disagreeable smells, discharge of coloured fats, acidulated water and danger of fire). The same holds good of establishments for removal of stains and dry cleaning (smell of the solvents, danger of fire). These establishments are therefore subject to a certain number of special regulations: construction of walls of incombustible materials (Buhrstone, cement), painting of the interior walls with cement wash, painting with oil paints of all rafters and exposed wood, impermeable flooring in courts and workrooms (jointed tiling), flooring of the latter to be of basin-shaped form1 in order to drain off spilled liquids and provided for the same reason with grooves or gratings; all apertures giving on to the public highway or on to adjoining properties kept closed; construction of vats in incombustible material; adoption wherever possible of indirect steam heating; placing of motors and hydro-extractors in such a manner that they offer no inconvenience for the neighbourhood (noise, vibration), etc.

Frequent washing of the workrooms with pure or chlorinater water.

Adequate apparatus for furnishing general ventilation, and especially for the elimination of clouds of steam, should be provided.

In the older types of dyeing establishments, ventilation is provided by means of large apertures, sometimes by skylights or cupolas. This irrational method, in cold weather, naturally increases the quantity of steam given off by the open vats. A transitory system is represented by the dyeing vat being placed under a more or less effective exhaust hood. This type offers, during cold weather, similar disadvantages to the former system of ventilation by large apertures; since the hoods in question may not be sufficiently lowered without hindering the worker in the execution of his work, cold air, coming from the outside, meets the air given off, and causes the generation of new clouds of steam at the edge of the vats; this becomes saturated, and further steam is generated. It is also necessary to take into account the possible risk of accidents likely to occur to the worker's head on account of the unduly

1 Concrete is not always advisable since it offers but slight resistance to hot acids and liquids. Earthenware impregnated with tar is good. The joins should be filled with asphalt.
low hoods (Gutmann). For this reason other types of hoods have been constructed with one or two doors or a sliding panel.

The system often followed, of placing vats in large workrooms provided with skylights at the top, or having exhaust ventilators of low pressure constructed near the top, is equally ineffective.

The only rational and practical system for eliminating steam, not so far, unfortunately, very extensively followed, consists in preventing steam from spreading through the workroom, or in retarding the saturation of the air, either by exhaust ventilation or by driving back the hot air, or by combining these two solutions. In certain circumstances, recourse is had to a single stream of hot air which is provided by natural ventilation. The installation of a ventilating system should be entrusted to experts, for many complicating factors require to be taken into consideration in order to ensure good results. It must be remembered that a good installation is a satisfactory investment, since the building and equipment will last longer and the efficiency of the workers, as well as the quality of the material turned out, are thereby improved.

S. Kossouroff and Pokrovsky (1928) report that good results have been obtained in a Russian establishment engaged in dyeing woollen cloth by means of a good system of ventilation installed over the vats and baths. These authorities found in the workrooms temperatures ranging from 24° to 28° C., and over some vats only a temperature of 32-36° with a relative humidity rate of 39.74 per cent. (over the open vats for boiling liquid, one of 97 per cent.). The research engaged in by them led them to conclude that with closed vats and adequate ventilation, it was possible to obtain satisfactory results, even in small workshops. The Esser apparatus, which give off a considerable amount of steam, should be situated in separate workrooms, and where possible under hoods provided with effective ventilation.

A closed dye vat (Raxhou type) offers the advantage of not giving off steam or mist at any season of the year. Dyeing is effected mechanically in an enclosed apparatus, and the steam is directly withdrawn to the outside of the workroom by means of a chimney installed above the apparatus. The worker has only to superintend the process, and is not exposed to the action of the hot liquid or the steam. Should the vat require to be opened whilst the process is in course of execution, the evacuating chimney opens automatically, and a device exists for ensuring immediate evacuation of the steam towards the outside. This apparatus is so constructed that every drop of condensed steam is withdrawn without any risk of staining the material. The temperature of the vat is regulated automatically by means of an electric thermoregulator (Baret).

The difficulties above referred to have also been met with in the United States, where certain establishments have adopted with advantage the system of "dyeing under pressure", which does not cause the liberation of steam clouds in the surrounding atmosphere. Several experiments have led to the conclusion that an exhaust rate of about 50 ft. per minute, applied above a vat provided with a well-installed hood, and capable of being closed "when necessary, suffices for the withdrawal of the steam given off by the boiling solution.

In many modern dye-works, in which a renewal of the air is provided for every three minutes by means of the mechanical ventilation ("plenum and vacuum" system), no mist is formed, and the atmosphere of the workroom remains quite clear. These factories of course provide for minute temperature control of the heated air, since an unduly high temperature would have an unfavourable influence on the health, and hence on the efficiency of the workers (J. V. Vogt).

Mention must be made of the proposal to utilise hygroscopic substances to absorb a part of the humidity present. There has been proposed the use of quicklime, chloride of calcium, etc., substances which, by reason of the quantity required, have so far rendered this method impracticable on account of the price.

In order to prevent the liberation of toxic products, certain operations such as, for instance, drying without heat and as far as possible in the open air under large hangars should be introduced. Dangerous processes should, as far as possible, be effected in closed apparatus; the vats used for soaking materials in cleaning should be provided with hermetically closed lids, and where technical requirements make this impossible, they should be placed under exhaust hoods, like the solution baths, dye-baths, etc. The same holds good of work at benches or over open vats. Apparatus such as hydro-extractors should be provided with wooden guards to protect the workers from the projection of liquid droplets. Drying should be effected in closed chambers which the workers are
not required to enter, and under a slightly negative pressure, to prevent possible escape of steam into the workrooms. The maintenance in motion of the air in these drying-rooms will facilitate drying. Adequate apparatus should be provided to ensure the recovery of the fumes given off in the course of the various operations (see article "Solvents").

An interesting report by Connell, Lamson and Ph. Drinker (1924) deals with dry-cleaning establishments in Boston, and reveals the fact that too often the same solvents are used in this industry an undue number of times, and that no means are employed for purifying them. The authorities in question suggest a standard of purity for solvents, as well as some very practical tests. The report analyses in detail the ventilation problem from the point of view of the health of the workers engaged, and that of the risk of fire.

Waste waters should be drawn off and directed into water courses which are neither used for domestic purposes nor as drinking-water by animals, and then only after requisite treatment. Where purification is impossible, it should in general be rendered illegal to direct this water into such channels, and it should be made compulsory to dispose of them by land treatment on special sewage disposal areas.

A good method for clarifying and decolorising waste water from dye-works is as follows: preliminary separation as far as possible of washing waters and used waters from dye-baths; regular ventilation of coloured water, with a view to precipitating the colouring matter in the vat dye and the majority of sulphuretted colouring agents; subsequent treatment by lime water; decantation, followed by filtration. The waters thus obtained, still slightly coloured, are treated by substances calculated to absorb the small remaining quantities of colouring agents which they contain (sawdust, different kinds of straw, grass, etc.). The elements of the wood facilitate absorption of the basic colouring agents, of sulphurous substances, and vat dyes, but to a lesser degree acid colouring agents. Where these predominate in the waste water, they should be absorbed as far as possible by residuary products obtained in the manufacture of leather tanned by the chrome process. Sawdust has the greatest affinity for colouring agents, and it even retains the colouring matter from colloidal solutions of indigo. The power of absorption of sawdust depends on the nature of the colouring agent and the proportion of waste water; the waters are made to pass continuously through layers of sawdust, and are emitted in a colourless condition. Absorption is slow, and practice has shown that sawdust takes about four days for saturation, whence the necessity for providing a quantity of sawdust four or five times greater than that required for absorption of the colouring matter from the waste water used in one day. The best results are obtained with the sawdust of hard woods, which contain less albuminous or tanning matter than soft woods. The latter contain resinous substances which do not absorb colour, or absorb it very little (Ginsberg).

In conclusion, there should be mentioned the importance of substituting as far as possible harmless products for toxic products.

Against risks of fire and explosion, all adequate measures should be applied, particularly in cleaning and scouring rooms, where every effort should be made to avoid the production and accumulation of static electricity in the apparatus (see article "Dust").

Very particular attention should be paid to measures for encouraging personal cleanliness; wash-basins, douche baths. Workers should be provided with working clothes (especially those workers whose clothes are liable to get wet in the course of operations), clogs, gloves, etc. Good cloakroom accommodation should be made available and should include arrangements for drying wet clothes, and lockers with two compartments, for town clothes and working clothes, or at least these should be so arranged that the two kinds of clothing should not be brought into contact. Workers should not be permitted to take meals into the workrooms, and canteens should be available, so arranged that workers should have meals there in comfort, and be able to heat them.

In certain cases medical supervision of the workers is necessary, in order that adequate measures may be taken in time for protecting their health.

LEGISLATION

In Argentina, women are absolutely excluded from dyeing establishments. In Belgium, in scouring and cleaning industries young persons under eighteen years of age are excluded from workshops in
which solvents are manipulated, in the dyeing industry they are excluded from workshops where toxic products are used. In Spain, the employment of boys under sixteen and girls under twenty-one in the dyeing industry is prohibited in those workshops where toxic substances are used. In Estonia, women and children under fifteen are excluded from operations in dyeing and printing calico, from the preparation of colours and mordants, from printing, steam-heating, the recovery of colouring substances, and from operations connected with the dyeing of material and dry-cleaning. In the United States, young persons under fifteen are excluded from the manufacture of toxic dyes (Delaware); this limit has been raised to sixteen years in other States (Alabama, California, Connecticut, Maryland, etc.). In France, women and boys under eighteen years are excluded from workshops where toxic substances are utilised. In Italy, boys under fifteen and women under twenty-one are excluded from dyeing establishments where colours and toxic products are prepared.

Legislation in the Netherlands demands compulsory notification of injuries met with amongst workers engaged in dyeing and printing textile and woven materials, poisoning by arsenic, skin diseases (eczematous and dermatitis), cancer of the skin and ulceration of the cornea and conjunctiva, and pulmonary troubles.

In France, compensation for lead poisoning is compulsory in the dyeing industry when colour with a lead basis is used. In the Dominions, compensation is obligatory for dermatitis due to dusts and liquids. In Queensland, that for dermatitis due to work in acid or mineralised water was provided by the Acts of 1916-1925, but only in the mining industry, in quarries and on the operations of stone-grinding and cutting. Amending legislation dated 1925, however, extends this form of compensation to work demanding the use of vegetable or mineral substances. The Acts of 1912-1924 in Western Australia include also compensation for eczematous ulceration of the skin due to whatever occupation may involve exposure to the action of dust, caustic liquids, corrosive substances, as well as ulceration of the nasal or buccal mucous membrane caused by dust. Compensation for poisoning may be covered by the formula adopted in the list (see article "Occupational Diseases: Compensation").

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Dyes


Dyes are generally classified as (a) "dyes" or "colorantes," properly so called, which have body, and dye by superposition, that is, by modifying the surface of objects, and (b) "dyes" without body which dye by impregnation, fixing either themselves, or through the use of mordants. In this latter class are grouped natural colours and artificial or synthetic colours derived from tar. There are, however, organic colours fixed on mineral substances, which belong to the first mentioned class (see article "Varnishes and Lacquers"). Other mineral colours are fixed or precipitated on fibres by means of coagulating materials.

Group (a) includes mineral colours, represented in general by metallic salts, or by natural or artificial mixtures. Natural white colours are chalk, kaolin and gypsum. Coloured earths obtained from the soil are crushed, powdered, sifted and sometimes calcined in order to modify the colour. Artificial mineral colours are white lead, red lead and vermilion; these colours, used for pottery and glass, can be vitrified or fused; when melted to a red heat they adhere to the surface of articles, so forming enamels. They are used in industry and the arts. They are found in commerce under a great variety of fancy names.

Vegetable colours are obtained by the oxidation or fermentation of plants (indigo, logwood, sorrel, cochineal and sandal wood) where they are already formed or exist in the form of chromogen, which is changed into a dye, or in the form of a glucoside. Sulphur colours constitute a very numerous series, which is obtained by melting such organic substances as amines, phenols, nitro-derivatives and coal-tar colours, with sulphur or sulphide of soda or chloride of sulphur. Generally this group comprises black, brown and blue colours; but it also includes green, yellow and violet. They are found in the form of pastes or powders, which sometimes have a disagreeable smell. Their composition is as a rule unknown, because the secret is closely guarded by the maker. When treated with hydrochloric acid and stannous chloride, these colours give off
sulphuretted hydrogen, and, when burnt, they give off sulphurous anhydride.

They are chiefly used for dyeing cotton, being used after a sulphur bath either by treatment with oxygenated water, or with bichromate or with hypochlorite or with metallic salts.

In practice these colours are classified as: (i) acid colours which dye animal fibres in an acid bath; (ii) basic which dye animal and vegetable fibres in a neutral bath; (iii) vegetable which require the preliminary use of tannin as a mordant; (iv) dyes acting with a mordant, which dye fibres previously mordanted with metallic oxides; (v) substances or semi-neutral dyes which dye, as do alkaline salts, textile fibres directly without the use of a mordant; (vi) insoluble dyes or pigments which form directly on the fibres and dye in a vat or develop on the fibre; (vii) dyes derived from casein are also known.

**INDUSTRIAL OPERATIONS**

As regards various dyes of mineral origin reference should be made to the corresponding articles. Here shall only be examined in detail the technique of the manufacture of _artificial organic colours_ (see also the article "Aniline").

In the early days, these colours were obtained by starting from the bases, aniline and toluidine; nowadays hydrocarbons are used as the starting point in the synthetic preparation of phenols and the bases.

Industry makes use of theoretical reactions established in the laboratories. The chromophore groups (— NO₂ — N — N —, etc.) make it possible to obtain chromogenic substances which themselves are not actually dyes, but become so by the introduction of other groups called auxochromes (— NH₂ — OH, etc.).

The reactions by which most of the intermediate substances can be obtained are:

**Chlorination.** — The introduction of chlorine, by means of ferric chloride or of pentachloride of antimony, either in the presence of catalysts or not, into an organic molecule by substitution, using saturated compounds, or by addition, using non-saturated compounds. The chlorine is made to act on the vapour of the hydrocarbon by light, or by cold with the hydrocarbons strongly illuminated.

** Sulphonation.** — The introduction of one or several sulphonic groups into the same nucleus, by the action of sulphuric acid, which is concentrated or charged with anhydride, at a somewhat high temperature, on the aromatic hydrocarbons and their derivatives. A toxic product is often changed by sulphonation into a harmless product.

**Alkaline fusion.** — Obtained by melting alkaline salts with soda. The sulphonic acids are changed into the corresponding phenols. Caustic soda is melted with a little water in an iron pot; the soda salt of the sulphonate derivative is thrown in while stirring all the time. The sulphite of soda, which is partly insoluble, is separated by filtration; it is rendered acid with sulphuric or hydrochloric acid, when the phenol is separated, with water if it is soluble, if not by passing in steam or by means of solvents.

**Nitration.** — The substitution for one or several hydrogen atoms in the aromatic nucleus of one or several nitrated groups, NO₂. This nitration is effected by nitric acid. The water formed during the reaction is absorbed by the concentrated sulphuric acid present. This mixture is called "sulphonitric mixture". The nitrate groups may be arranged in different ways, by using a mixture of sulphuric acid and nitrate of soda, or of nitric acid and acetic anhydride.

**Reduction.** — By means of free hydrogen either in the presence or not of catalysts, a chemical compound may be made to pass to a lower degree of oxidation. The free hydrogen can be replaced by a substance which generates hydrogen, or is more oxidizable than the body to be reduced. The operation is carried out in an acid, neutral or alkaline medium, in order to change the nitrated derivatives into corresponding amines or into substituted hydroxylamines or into oxazo compounds. Amines give by nitration the nitrated derivatives of amines, which are also obtained by the partial reduction of polynitrated derivatives: aniline from nitrobenzene; ortho- and para-toluidine from nitrotoluene; and phenyldiamine from DNB.

**Alcyolation.** — A methyl- or ethyl-alcohol radicle is substituted for the hydrogen of phenolic oxhydride of phenol or of the aminated group of amines.

Among the other complementary operations, may be mentioned: _oxidation_ by means of chlorates, bichromates, permanganates, manganese dioxide, peroxide of lead and a mineral acid; _carboxylation_, by making caustic soda and pure carbonic anhydride to act on phenol, in this way a group COOH being introduced; _condensation_, which results in combining two compounds or two molecules of the same product to form a new one, with loss.
of water or hydrochloric acid or ammonia, and is assisted by the presence of phosphorus, zinc, tin or sulphur; and also dinitration.

The products obtained, rapidly enumerated, are as follows:

**Nitrate colours.**—Derived from phenols, naphthols, and their sulphonic acids. These colours are of medium importance.

**Nitrite colours.**—Benzenic (chrysoidene and vesuvine), naphthalenic (poppy red, claret, orange, azofuchsin), dimetric, nitric not substantive; substantive or direct for cotton (Congo red and dimame brown) from benzidine.

**Hydrazones.**—The phenylhydrazones are obtained by the reaction of phenylhydrazine and its substituted derivatives on aldehydes, ketones and quinones. This group includes some coloured bodies and true dyes.

**Nitrosed colours.**—Obtained by the action of nitrous acid on the phenols. An acidulated solution of phenol is treated by nitrite of soda at about 0° C. and poured gently into a cold acid liquor; the derived nitrate so formed is precipitated by common salt. These colours can be obtained by heating the phenol in an alcoholic solution with nitrite of soda and such a metallic salt as chloride of zinc.

**Diphenylmethane.**—Includes auramine and pyronine. Triphenylmethane is the nucleus of a large number of dyes, which are classed under the amine derivatives, of which the auxochromes are basic groups (fuchsin, malachite green) and derivatives of phthalic acid, of which the auxochromes are the hydroxyle groups (aurine, etc.).

**Quinone-imide.**—Connected to the imides of quinone (indamines, indo-phenols, thiazines, oxazines, azines); methylene blue, brilliant blue, alizarine, safrafinines and indulines.

**Aniline black.**—An insoluble dye furnished by the action of oxidising acids, such as chlorates and bichromates, on a salt of aniline, in the presence of a metallic salt of copper, iron or vanadium, an action which has for its object the setting free of chloric or chromic acid and of transporting oxygen to the aniline. In practice it is always prepared on the fibre by means of a bath of chlorohydrate of aniline, bichromate and a catalyst which is either cold or not. Then follows washing with soap and a bichromate bath to increase the resistance to acids. The oxidation or the prussiate methods are also used.

**Quinoline; acridine.**—These amine derivatives in the state of salt are yellow and little used.

**Thiazolic colours.**—These are obtained by melting paratoluidine or its homologues with sulphur.

**Anthracene colours.**—Include: the hydroxyle colours, e.g. alizarine purpurin, anthracene blue and alizarine claret; the amine colours obtained by the reduction of nitroanthraquinones, or by the action of ammonia, or its amines on the substituted anthraquinones by the negative radicles; the oxyamine colours obtained by means of nitroanthraquinones or by the action of ammonia on the polyoxyanthraquinones; alizarine blue, and then the colours for the dyeing tub derived from anthraquinone. Anthraquinone is changed by alkaline reducers into oxanthrol, which with alkalis gives red solutions and becomes reoxidised on exposure to the air into anthraquinone; series of indanthrene and of flavanthrene.

**Indigo.**—Synthetic indigo is obtained by starting from phenyglycoccoll or anthranilic acid. There are several halogens derived from indigo.

### Sources of Injury

It would take too long to give here a full list of the products which, in the solid, liquid or gaseous form, may become sources of real danger of poisoning for industrial workers on organic colours: mineral and organic acids, alcohols, ethers, carbon monoxide, phosgene, sulpherflet hydrogen, arsenic fumes and ammonia; narcotic substances: chlorated hydrocarbons; substances which are easily inflammable and explosive if their vapours gain access to the air: benzene, toluene, naphtha solvent, chlorbenzene, petrol and sulphide of carbon; substances with an irritating caustic action on the skin and mucous membranes: alkalis, acids, chromates, bichromates, chlorides of benzol and benzyl, phenols and cresols; substances which can be absorbed through the skin: nitrate derivatives of benzene and its homologues, aniline, toluidine and naphthylamine. At first arsenic was used in the dye industry as an oxidising agent in the preparation of colours of the fuchsin group; now it is no longer used at all.

The processes in the manufacture of artificial organic colours are complicated and sometimes secret. Further, they vary in different works. However, that may be, it is not possible to generalise because the conditions vary much
according to the method of preparation and the products used. The hazards in the various operations, according to Hamilton, may be sketched as follows:

The use of nitro-amino derivatives is associated with serious risk from poisoning: the group of raw naphthenionics; DNB; diamines, aniline colours poisoning: the group of raw naphthenionics; benzoic and salicylic acids, aniline blue and alkali blue; drying of phenylglycine; anthraquinone, pyridine and yellow indanthrene.

The handling of nitro-amino derivatives is associated with less danger, because there is no contact with the poisons, or the poison is less severe; purification of para-nitraniline; of beta derivatives, or the poison is no contact with the metal or acid.

The causes of injury may be the following products in the operations of:

**Sulphonation:** benzene, aniline, toluidene, sulphurous anhydride (given off).

**Alkaline fusion:** alkalis in the form of solids, liquids and vapours: caustic action, the risk of serious burns, of explosion and leaks from the autoclave.

**Nitration:** acids, acid fumes and nitrous gas. The nitrated compound obtained is more poisonous than the original product. The nitrated product is present in considerable proportions, say 20 per cent., in the residuary acid.

**Reduction:** splashings during sampling. Serious cases if the apparatus leaks or explodes (aniline). The reduction of DNB to phenylendiamine is dangerous. When reduction is done by the zinc and caustic soda process, or by the acid method, danger arises from the possible presence of arsenic in the metal or acid.

**Chlorination:** vapours of chlorine and hydrochloric acid.

**Alcoylation:** methyl alcohol and aniline.

**Oxidation:** quinones and chromates.

**Condensation:** accidentally, toxic vapours and splashings.

**Nitric colours:** a safe section, without danger, if intermediaries are not prepared.

**Anthracene:** without great risks. The danger in the preparation of indanthrene colours is more serious. For violet and green colours; chlorine, nitrobenzene, nitric acid.

**Indigo:** the risks vary according to the method of manufacture: formaldehyde, aniline, cyanide of sodium (added or formed), ammonia, phenylglycine (filtering, drying and transport) containing unchanged aniline (a serious cause of danger, for the dust is light and difficult to transport and pack in barrels), monochloracetic acid which is very caustic.

**Di- and triphenylmethane:** all the nitrato and amino derivatives of benzene and its homologues.

**Pyrene-eosine:** chlorine, bromine, iodine. Manufacture in closed apparatus.

**Nitroses:** picric acid, and aurantia, with danger at the moment of nitration.

**Sulphides:** sulphuretted hydrogen: intermediaries such as para-nitrochlorobenzene; chlorobenzene; nitro- and para-nitrophenol; and dinitrochlorobenzene for the black.

**Aniline black:** aniline and vanadium.

**TOXIC EFFECT**

Speaking generally, aniline colours prepared by modern methods may be said not to be injurious either for the chemists or workers. Indeed, poisoning by these colours has become more and more rare and is confined to local affections of the skin and the visible mucous membranes, especially of the eye. For the effect of the products the colours are originally prepared from, and of intermediate products, see the corresponding articles. It is not necessary to insist here on the injurious effect of lime, acids and alkalis.

As regards the colours themselves, Weyl has examined ninety-six aniline colours which he considered toxic (quoted by Koelsch).

Chlopin (1903) studied fifty organic colours prepared at that time, and, by experiments in which large dogs were fed several times a day with 5-10 grnm. per kg. of animal, he came to the conclusion that, for example, aurantia, orange II, methyl orange, yellow butter colour, auramine O, brilliant green, aurine, the R true blue for cotton, ursol D and Widal black, should be considered
as poisonous, whilst on the other
hand yellow metanyle, aniline orange
t, poppy red RR, benzopurpurin,
yellow lemon and acid green, should be
considered as suspect. But it should
be said that, in practice, workers are
never exposed to doses as high as those
reported in the laboratory experiment.
Some investigations made by Chlopin
into the occurrence of skin lesions in
man, by the application of compresses
soaked in colours, have not given strik-

ing results.

Thus twenty-four colours studied by
Bachfeld did not cause any injury, ex-
cept two cases of dermatitis. Weyl,
taking up again later the study of these
colours, admits that as a rule they are
neither irritating nor toxic, with the
exception of a few only, e.g. para-
midophenol, para-nitroaniline and dia-
midophenol. Blaschko considers that an
important factor in the lesions due to
aniline colours is represented by the
substances mixed with the colours when
using them, such as oils of turpentine,
alcohols and solvents. In the same
way, the means used for cleaning the
hands — chloride of lime, soda, pumice
stone or black soap — favour the effect
of the aniline colours on the skin.
These colours, which generally and
theoretically injure the skin by acting
directly on the cellular protoplasm (the
basic colours acting more strongly than
the acid: Vogt), can be regarded in
practice as harmless. Hence Bachfeld
said that a harmful effect could scarcely
be ascribed to 300 colours manufactured
at Offenbach. It is only to a very
small number of colours that a general
effect with cyanosis associated with a
pale blue colour of the ears and lips,
advancing to a blackish colour of the
whole body, and jaundice, can be at-
tributed.

As regards the mucous membranes,
especially that of the eye, it may be
asked whether the action of these
colours is similar to that of inert
foreign bodies.

In 1897 Senn reported several cases
of conjunctivitis which he attributed to
the action of hot vapours arising from
dyeing tubs and quinone vats (see arti-
cle "Dyeworks"). These observations
formed the starting point of the ex-
perimental and clinical investigations
of Vogt (1905) who concluded that
aniline colours exercise on the eyes an
action which varies according to their
chemical properties. Thus, for exam-
ple, basic colours are more toxic than
acid or neutral, which, when injected
even in a large quantity (5-10 mg.) into
the conjunctival sac, cause very little
or no irritation. The basic colours, on
the other hand, cause, as they
dissociate, serious inflammatory symp-
toms, the intensity of which is greater
in proportion as the colour is more
basic and more soluble. Out of 17 cases
of eye lesions observed by Vogt there
were 7 of keratitis and 10 of conjuncti-
visis which might be attributed (1905).

As regards cases of chronic anilism the
enquiry showed 5 cases of gastro-intestinal
disorders due to fuchsine and 2 to blues;
5 cases of giddiness, headaches and
vertigo due to fuchsine and 5 to blues;
2 of cyanosis of the lips due to fuchsine
and 3 to blues; 7 of urobilinuria due to
fuchsine and 4 to blues. In the blues sec-
tion it was found that nearly all the work-
ers (9 out of 10) had lymphocytosis; in
one there was found eosinophilia, which
was also found in one worker of the
amino-nitro-benzene section. In this sec-
tion, congestion of the pharynx was found
in two workers. In about a third of all
the workers examined the authors found a
few red blood corpuscles with very fine
granulations.
Germany

According to Wolf, the workers of an aniline colour factory at Griesheim experienced, during the period 1883-1893, the following rates of sickness per 100 workers: dermatitis from sulphuric acid, 4.7; from nitric acid, 5.0; from chromates, 5; from hydrochloric acid sulphates, 7.4; from salts of soda, 8.9; from sulphur, 11.4; from caustic soda, 11.4; from aniline oil, 12.2; from picric acid, 12.4; from chloride of lime and caustic potash, 12.5.

According to Grandhomme, the cases of eczema among workers in aniline colours during the period 1883-1893 were 34.7 per 100 workers in the aniline section; 15.8 in that of alizarine; 23 in that of acids; 27.6 in the furnace section. During the period 1892 to 1893 the cases of dermatitis per 100 workers were 9.4 in the section of acids; 11 in that of furnaces; 11 in that of alizarine; 11.7 in that of aniline and colours; and 11.7 in the chemical laboratories.

Certain statistics collected by Leymann and Curschmann are very detailed; they relate to large factories and deal with a long period of observation (1879-1913).

In a large colour factory the cases of internal affections found from 1879 to 1911 among 37,409 persons, with a yearly average of 1,169, reached a total of 14,336, or 380.5 cases per annum, or an average of 884 per annum and of 75.6 per 100 persons with 417,254 days of sickness, at the rate of 13,039 per annum and 11.2 days of sickness per worker.

Out of 100 external lesions per annum burns figure with rates of 4.76 from fire; 6.73 from water; 4.42 from acids; 3.51 from alkalis. The cases caused by hot water and acids developed slowly. In another factory from 1892 to 1911 out of 24,367 persons there were 1,977 cases of dermatitis, lympanghitis and adenitis, or 14.12 per annum and 8 per 100 persons; 554 burns by chemical products, or 39.6 per annum and 2.3 per 100; 164 burns by fire, hot water or steam, or 11.7 per annum and 0.7 per 100; 340 cases of eye lesions of traumatic origin, or 24.3 per annum and 1.4 per 100. A total of 3,038 cases; that is, 217 per annum and 12.4 per 100 workers.

Analysis of these statistics, which cover long periods of time, shows a diminution in the cases of poisoning, from 15.7 in 1888-1904 to 10.6 in 1897-1911.

The statistics collected by Bachfeld at Offenbach during the period 1909-1914 are also interesting. Among 4,945 workers, he found in six years 139 cases of dermatitis, 32 of whom were incapacitated for 595 days, i.e. 26.50 cases per annum, 5.33 of whom had an incapacity of 89.16 days. Per full working complement of 100 workers there occurred every year 3.21 cases, of whom 0.26 had an incapacity of 12.30 days.

The 159 cases of dermatitis were made up as follows: 104 cases of eczema; 37 of rhagades and ulcers; 18 of hyperhydrosis. Twenty-seven cases were caused by raw materials and intermediate products; 46 by the manufacture of colours; 7 by the finished goods; 4 during their storage. These 85 cases affected 70 men.

As regards eye lesions Bachfeld found 274 cases of whom 25 were incapacitated (40.66 per annum). Of these cases 42 were lesions due to foreign bodies, composed of methyl violet and methyl green, which had penetrated into the eye; 30 cases have been reported in the other sections.

Great Britain

Cases of injury caused by dyes are given under different headings, such as "Dyeing" and "Dermatitis", and the reader is referred to those articles. In 1921 an interesting enquiry on the preparation of aniline black was made by Henry and Williamson (see article "Aniline"). Other cases of injury by this product were reported in 1926 (cf the report of the Senior Medical Inspector).

Speaking generally, dermatitis is the chief trouble, and among the notifications received by the medical service the following percentages occurred: 1924, 17.7; 1925, 10.1; 1926, 7.1; 1927, 6.5; 1928, 4.8.

Italy

An enquiry of Aiello and Chiossèf, made in 1928, in several aniline colour works and dyeworks of Lombardy, disclosed some cases of cyanosis and headache, which the investigators attributed to aniline. Clinical examination of the
workers was confirmed by analysis of the blood and urine. The authors found leucopenia, secondary anaemia and lymphocytosis with neutrophilopoenia. In 40 per cent. of the workers employed in certain sections of the works, preparing aniline black and aniline blue, they found aniline and urobilin in the urine.

Switzerland

A factory employing 800 workers had 64 of them affected with slight dermatitis, but only 22 were incapable of work and these caused a total of 277 days of lost-time.

An accident occurred, due to the explosion of black aniline during crushing, caused by a containing a certain quantity of chlorate of potash.

United States

Hamilton has supplied the statistical data. A firm, employing 850 workers in the works and 400 persons in the laboratories, had during a single summer month in 1918 the following cases of sickness:

From nitro-amino derivatives: new cases, 29; old cases under treatment, 255; scalds and burns by alkalis, 82; eye injuries due to acids, 20; ditto by conjunctivitis, 29; ditto by alkalis, 26; poisoning by chlorine vapour, 1. The measures of precaution adopted, by exhaust ventilation for vapours, liquids and solids, by personal protection, and by early treatment, have reduced to 61 days the days lost in December and to nothing the days lost in June 1919, with an increase of 340,000 pounds of output.

In another factory with 700-1,600 workers, 100 of whom were in the laboratory, there were found, during six months in 1918, among 1,649 persons, 356 acute cases, of whom 63 had disorders of the digestive organs, 69 of the respiratory passages, including catarrhs, coughs and influenza, 37 of the skin, 72 of the eyes, 12 of the locomotor apparatus including rheumatism; 13 were cases of cephalgia; 27 of abscess; and 43 of various kinds. The sick rate among the office staff under attention was 5.5 per cent.; among the mechanics, 18.5; among the laboratory personnel, 18.6; among those handling raw materials, 22.6; among the personnel in contact with the colours, 27; and among those in contact with intermediate products, 28.3.

Twenty-eight accidents caused 1,779 days of incapacity; 103 only of some hours. The accidents were caused chiefly by hot vapours and liquids (20), acids (31), burns of the eyes caused by acids (17), caustics (12), and caustic soda (16).

PATHOLOGY

The pathology is very complex, because it depends on the action of different products often acting at the same time. For the purpose of a summary there is given here, grouped by the symptoms found, the list of products which are found enumerated in the literature on the subject. Naturally this list has no pretensions to be complete.

Lesions of the skin pass from simple irritation with redness, itching, oedema, to the most diverse eruptions, eczema, warts and even to epidermolysis.

Some cases of dermatitis have been reported from hexanitrodiphenylamine (Koelsch, Hoffmann); from nitric colour's ("the itch of nitrites") which may be due rather to the presence of nitrosed intermediates; from fuchsin (case of Bachfeld, due perhaps to purifying agents rather than to the colour itself); from alizarine (six cases due perhaps to impurities); from aurantia; from nitrosodimethylaniline; from triphenylmethane; from triphehylrosaniline, marine blue, crystal green, triphenyl coralline (little used); from violet crayons (with methyl violet); eosin, erythrosine, with their well known photodynamic action; paraphenyldiamine; chrysoidine (Von Jaksch); from trua yellow, aniline yellow, metanile yellow; vesuvine; Bismarck brown; the new blue R; the yellow butter colour; the para red; the sulphur colours (5 cases in six years: Bachfeld does not, however, exclude the action of other products); primuline, which is very irritating, according to Prosser White; Martius yellow, napthol yellow, and Manchester yellow.

Frequently these colours stain the skin, nails or hair by depositing soluble colours in the sweat, or steam. As a rule a good wash removes them; others, on the contrary, such as picric acid, are very resistant.

The lesions occur on the face, hands, feet, and later spread all over the body. The rash and oedema often occur on the scrotum and penis. In serious cases a bullous dermatitis with loss of the epidermis is found. These forms have generally a sudden acute onset and are followed by a state of resistance or immunity which lasts several years. But there are a large number of cases of idiosyncrasy with great sensitiveness to one or other of the products handled. Oedema is added to the cutaneous lesion in cases due to hexanitrodiphenylamine, marine blue, brilliant and crystal green, triphehylrosaniline, violet crayons (methyl violet), eosin, chrysoidin and primuline. Eczema has been found several times and definitely in cases due, for example, to true marine blue (in powder), aurantia, black aniline (even among workers working on dyed wool), "rongalite" (a salt of formaldehyde...
sulphoxalate used as a mordant), ruby-fuchsin, which, according to Sachs, has caused a verrucose eczema among workers handling the wool dyed with acid fuchsin; chrysoidine or diamino-nitrobenzene (Von Jaksch); Safranine, benzidine colours, Martius yellow, Manchester yellow, anthracene and acridine colours, antraquinone and anthranarine (red reduced alizarine).

There should be recalled the aseptic necrosis caused by the aniline pencil, reported by French, German and Austrian writers. Some millimetres of the aniline part of the pencil, when buried in the skin, act as a caustic and destroy the tissues in contact with it. Iselin calls this lesion "aseptic chemical necrosis"; but although it generally acts in a purely local manner, some German authors have reported the possibility of general poisoning which is manifested by fatigue, headaches and loss of appetite, and sometimes even by a slight degree of mild icterus.

The important point to bear in mind is that the bit of aniline which has penetrated the skin remains there, and preserves for a long time its power of destruction.

An irritation of the mucous membranes which is more or less serious has been reported from the action of true marine blue, new blue R, yellow butter colour, red paranitraniline azo colours, anthracene and acridine. It is chiefly the ocular and sclerotic conjunctiva which are affected by methyl violet, triphenylmethane (which may even cause necrosis of the eye), violet pencils, the colours of anthracene, acridine, nitronaphthaline and safranine.

Eye lesions are very common and are most often due to intermediate products and the habit workers have of rubbing their eyes with dirty hands. Among the colours which cause the greatest number of lesions of the eye, are methyl violet and methyl green, the cornea being often dyed brown or sepia. Aniline black causes bullae which on healing leave a scar corresponding to the palpebral opening; vapours of quinone have caused corneal stains which the action of light turns to brown due to reduction of the colouring solution.

In some cases experts have found serious conjunctivitis, chemoses, oedema of the lids and opacity of the cornea; sometimes deep ulcerations with coloration of the aqueous humour. Experimentally, it has been found that it is chiefly the basic colours which do most damage to the tissues, whilst acid colours are readily eliminated by the tears. In a case reported by Kraemer the eye was deeply stained by indigo blue. The irritation lasted some time and the cure was very slow. Out of 77 eye lesions reported by specialists, 14 were conjunctivitis and 36 were of the cornea. Bachfeld, in six years only found 43 lesions from the use of aniline colours, only 7 cases of which were incapacitated.

A very limited number of colours have caused a general reaction in the system. There may be mentioned lyp mangitis, and the pains caused by hexanitrodiphenylamine; the pains and malaise caused by methyl violet; cyanosis due to nigrosine; the slight form of anilism caused by aniline black (Williamson) with pallor, cyanosis, trembling, dyspnoea, nausea, vertigo, headaches and weakness; by chrysolidine (Von Jaksch); serious or fatal cases among workers making the black derivatives of mono- and dinitrophenol, nitrochlorbenzene, and a fatal case (White and Sellers) in a worker who prepared the chlorhydrate of triphenylmethane black dye some skeins black. Acid fuchsin has caused digestive disorders (Sachs). Methylene blue, on the other hand, has never caused any disturbance and is confined to colouring the sweat blue. But pure fuchsin without arsenic — chlorhydrate of rosaniline — is not as harmless as has been generally held, for according to Rubino and Tedeschi it changes the haemoglobin in the circulating blood into methaemoglobin, just as ethyl green or malachite green do. Notice should be taken of a case of papilloma described in 1911 by Sachs affecting a painter who had worked for nine months with triphenylmethane. The papilloma was situated on the face and one arm. In a woman a papilloma was situated on the hands (fingers) and was due to the use of wool also died with triphenylmethane. The scarlet red and brilliant red caused an epithelioma in a lithographer aged twenty-nine years (Sachs). As regards papillomatosis of the bladder, see articles "Aniline", "Anthracene", "Occupational Diseases: Urogenital System", "Occupational Tumours".

**HYGIENE**

This is the same as that of the chemical industry generally and of the manufacture of nitro-amino derivatives in particular (see these articles, as well as the articles "Aniline", "Anthracene", "Benzidine", etc.; see also the article "Waste Waters").

It is perhaps fitting to mention here that Vogt has found that 5-10 per cent. solutions of tannin are very useful for treating eye lesions caused by aniline. He recommends a mixture of a 5 per
cent. solution of tannin and a 3 per cent. solution of boric acid, for free irrigation of the eye. According to Vogt, irrigation with this solution gives results which are much superior to those obtained by peroxide of hydrogen.

**LEGISLATION**

Women are excluded from aniline colour works in Argentina and France; boys under sixteen years and young girls under eighteen in Greece; boys under fifteen years and girls under twenty-one in Italy. In Belgium young persons under sixteen years are excluded from processes in which colours are applied while hot to paper, wood, stuff, and generally to any material of whatever kind.

Legislation is generally that laid down for the chemical industry and in particular for factories making nitro-amino derivatives (see that article). Injuries due to aniline colours are compensated in Finland; in other countries they may come under the same heading as nitro-amino derivatives. As regards metallic colours, see articles “Lead”, “Mercury”, etc. Thus for example, France compensates certain lesions due to lead colours. The Netherlands requires a notification of dermatitis and eczema occurring among those employed in making paints and colours; Finland compensates injuries caused by aniline colours.

**BIBLIOGRAPHY**


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Effort
(Strain)


GENERAL CONSIDERATIONS

By "effort", in the wide sense of the word, is meant bringing into voluntary action the reserve of physico-psychical energy, accumulated in a potential state in the body, with a view to the accomplishment of a task where it is necessary to overcome abnormal resistances or, at any rate, resistances superior to everyday needs. The word "effort", moreover, can be applied equally well to manual or to intellectual work.

Numerous definitions of physical effort have been given: "Effort, as understood physiologically, consists in an attempt at energy during expiration while the glottis is closed preventing this expiration from taking effect" (Marey). "Rapid and excessive work of the muscles" (Mantegazza). "Effort properly defined is identical with an effort of thoraco-abdominal pressure, that is to say, with a total combined muscular energy of such a nature that the trunk becomes rigid and forms a point where enabling the peripheral muscles to be brought into play or even to enter into action as a lever" (Born).

These definitions, like a certain number of others, are neither complete nor exact, because they only define effort in relation to certain of its varieties and to certain of its effects.

Pieraccini's definition: "Physical effort in man is substantially that which calls for all the muscular energy to overcome an obstacle" is more precise.

Effort, for Mori, is "a general and local muscular action, the intensity, duration and variety of which, in carrying out a set piece of work, exceeds the normal rhythm habitual to the subject".

Effort can be general or local. It is general or total when all the muscles of the limbs and trunk enter into contraction; it is local, or partial, when one muscular group only, or several muscles of a given area, which control a set function enter into activity. It is, however, true that, while in the general effort there is one particular muscle group which takes supremacy over the others by reason of the object in view of the localised effort, or even if a combined group enters into effective action, the other muscles and especially the antagonistic muscles are not inactive. The action of these latter, called the "antagonistic", which oppose apparently a given movement, have a great part to play in regulating, focusing and directing the total effort of the muscular actions.

The word "effort" is wrongly used by some writers to indicate dangerous effects which can arise from excessive muscular action. In common language "strain" is an effect synonymous with tearing of the muscles, etc. It is difficult, if not impossible, to determine the point where normal muscular action ends and where effort commences, because the two actions cannot be separated by clearly defined lines and we have no means of measuring when muscular energy exceeds the physiological limit and work is done with effort.

It should be added that the muscular force developed in man varies from one individual to another in proportion to the constitution of the subject, the development of the muscular masses and of the skeleton, to the degree of health and personal fitness, especially to the degree of physical education but principally to exercise, which is of all the factors of bodily energy without doubt the most important.

While effort represents a state of activity above physiological limits, it has its effect on the organism leading to the development of injurious effects which may happen suddenly during the act of effort itself, or gradually by the accumulation of each one of the injurious effects repeated one after the other.

PATHOGENESIS

These efforts can be general or local and may affect: (a) the organs themselves, those which generate the force (tendons, muscles and neighbouring parts, aponeurosis, fibrous sheaths, synovial membranes, serous bursae); (b) the tissues and organs in direct relation with the muscular force (bones and joints); (c) the organs subjected to the effort under the functional strain of the muscles (visceral contents of the thorax and abdomen); (d) the other
organs apparently not subjected to the action of effort by the muscular forces, but which, on the contrary, will feel the reaction of the effects of the mechanism of effort, as, e.g., the circulation represented by the heart and blood muscles.

In order to study properly, however, the pathogenesis of the different lesions due to effort the mechanism of physical effort must first be studied.

According to the classical point of view general effort is composed of three periods: (1) deep inspiration; (2) closure of the glottis; (3) contraction of the thoraco-abdominal muscles with simultaneous setting in action of the arm and leg muscles or limited groups of muscles. Then ensues a deep inspiration so as to expand the lungs and hold as large a quantity of air as possible; closure of the glottis, which prevents the escape of the inspired air; entry into action at the same time of the mass of thoraco-abdominal muscles, which, immobilising the trunk, converts it into a support for putting into action all the levers or a part of them as in the case of the four limbs, more rarely of the trunk itself, and more rarely still of the neck and head (thrust forward from the shoulder or from the head).

This muscular contraction, carried to its maximum brings about a reduction in the thoraco-abdominal cavities as far as the organs contained therein allow, and determines a notable increase in the endo-thoracic and endo-abdominal pressure, but more particularly in the latter. The abdominal cavity really, in addition to the pressure exerted by its own muscular walls, is subjected to the pressure from the diaphragm, the arch of which is depressed to increase the endo-thoracic pressure. The viscera within the cavity (lungs, heart, intestines and stomach, etc., as well as the blood vessels) are subjected to strong compression, which makes its injurious action felt even on certain peripheral organs standing in correlation with the viscera. Direct examination of a man at the height of a powerful effort shows up the state of contraction of the muscles of the trunk, the congestion of the face, the turgid swelling of the veins of the neck and veins of the upper and lower limbs; further, during certain efforts the muscles of the thoracic walls especially are brought into play (e.g. in the act of breaking a pebble with a club) causing a noise in the air inspired and expired respectively at each rise and fall of the tool. In the effort the radial pulse is no longer felt and there is diminution in the clearness with which the sounds of the heart are heard; an increase in the pressure of air in the bronchial tubes amounting to 12 to 14 cm. of mercury (experiment of Marey); alignment of the edges of the glottis (Longet); and in subjects who have a fistulous opening of the trachea air escapes, according to Bourdon, with a whistling sound from the said opening.

Pieraccini has taken up again the study of this question and, starting from considerations partly teleological, has thrown doubt on the exactness of the facts on which the classical theory of effort is based. By an analytical revision and experiments, he thinks it necessary, partially at least, to modify this conception.

Pieraccini, taking suitable subjects and using a simple apparatus, and varying his methods slightly according to the necessities of the different experiments, has undertaken during the act of effort: first, how the endo-thoracic and endo-abdominal pressure are affected; next, the variations in the cerebral and cerebro-spinal pressure, as well as in the main arteries themselves. Analysis of the different manifestations of effort in its relations with the successive phases enabled him to distinguish three periods: (a) a fore-effort period corresponding to the state of the body in immediate preparation for the effort; (b) the phase of effort itself comprising the whole of the period during which the muscular energy is acting; (c) the post-effort period extending from the moment of relaxation of the muscles to the return of the pulse and respiratory movements to normal (rest period). He further distinguishes the muscular effort (by which he understands the effort of energetic and violent effort), according to its duration, as short (two or three minutes), average (four to six minutes), and prolonged (seven to ten minutes).

It is unnecessary to give details of the apparatus used by Pieraccini in provoking the muscular effort in his test individuals, which took the form of traction, lifting (of sacks full of sand and weighing 25-35 kg.), etc.

From the results of his investigations, Pieraccini thinks that, contrary to what has been accepted hitherto, as regards muscular effort, the endo-thoracic pressure (which is the same thing as the pulmonary) is equal to that of the external air, and if the voluntary act sometimes commences with an inspiration or expiration greater than usual, that is most probably connected with a special adaptation of the thoracic cavity of greater or less amplitude, but in no wise involves an endo-
thoracic pressure higher or lower than normal. Under the voluntary effort the glottis definitely closes and folds on itself in proportion as the effort increases, to lock itself completely at the culminating point of the effort. If this effort is effected briskly the glottis closes energetically and promptly.

**Fig. 78.** — Respiratory tracing taken during an effort made with a dynamometer: (a) breathing suspended; (b) end of the effort: deep breath followed by a normal respiration: deep breath.

**Fig. 79.** — The uppermost tracing marks the increased rapidity in breathing during the dynamometric effort (see the middle tracing). The third tracing indicates the time.

**Fig. 80.** — Oscillations of the endo-gastric pressure during effort, measured by means of an exploring tube introduced into the stomach.

**Fig. 81.** — Increase in the endo-vaginal pressure: (c) during voluntary physical effort; (b-a) normal respiratory oscillations. (G. Pieraccini.)

During the phase of effort, respiration stops and the pause for the effort coincides more particularly with the acme of the inspiratory phase.

Generally the equalisation of the endo-pulmonary pressure and the outside pressure is not preceded by any change in the normal movements of the respiratory act. When the effort is accomplished as an isolated act, that is to say, by interrupting the normal rest of the body, the respiratory rhythm quickly returns to normal (see figs. 78 and 79).

The amplitude and frequency of the respiratory acts are in proportional relation to the intensity and duration of the effort and to effort that is single or repeated or accompanied by muscular work.

The graph showing respiration during effort is still in relation to the attitudes assumed by the body in the effort, particularly with those of the trunk and arms taken in the period prior to effort and during the effort which depends on the muscles and levers entering into action. Certain manual labours demanding rhythmic sequence in the muscular energy employed, as for example the felling of a tree with an axe or the breaking of a pebble with a hammer, commence with an inspiration and end with an explosive expiration synchronous with the final phase of the effort.

On the other hand, the act of squeezing an india-rubber ball with the hand or exercising violent traction with the two hands stretched out horizontally in a state of high tension (striking with the two hands on two bells placed on each side of the body at the level of the shoulder) presents an opposite condition.

During reflex effort (coughing, defaecation, etc.), the endo-thoracic pressure rises in proportion to the intensity of these acts.

The endo-abdominal pressure in a voluntary physical effort increases in a notable and rapid manner and the fall is also rapid with the cessation of the effort. The augmentation in the endo-abdominal pressure occurs again in reflex action (pushing, micturition) (figs. 80 and 81).

In voluntary effort the diaphragm rises, that is to say, its convexity becomes accentuated in the direction of the thoracic cavity while in involuntary effort it descends.

The endo-cranial pressure which normally depends on the state of the heart is slightly and transiently raised during the earliest stage of pre-effort. In the phase of effort a substantial increase takes place which is maintained within the limits of the normal arterial oscillations; in the post-effort phase, when the muscles relax the pressure shows a sharp fall, constant and notable, a real and definite fall.

The endo-spinal pressure in the spinal cord increases both in voluntary and in reflex physical effort.

In voluntary and involuntary physical effort the pupils dilate in pro-
portion to the effort although the extent varies with the individual. This dilation is due, according to Pieraccini, to vasodilatation of the sympathetic nervous system.

During voluntary physical effort an increase in the general arterial pressure occurs, just as there is an increase in the blood pressure in the area of venous and arterial vascular distribution, in the muscular segment implicated in a circumscribed effort. The venous pressure increases in physical effort in direct proportion to the effort, as has been shown by Delbet.

In consequence of the changes in blood pressure in the general circulation as a consequence of sharp and violent effort, a rapid and proportional repercussion shows itself on the pulmonary circulation. During the phase of effort there is an increase in the endo-pulmonary vascular pressure as a kind of reaction, without taking into consideration the other eventual coefficients.

These experiments establishing in the matter of effort the teleological principle which seems to dominate all the facts of biology, rectify largely the classical theory. They confirm certain facts already observed on the clinical side and, further, give the key for explaining more rationally certain morbid effects which may result from effort. On the other hand, in order to understand better the effects which may eventually be due to effort account must be taken of the intensity and duration, and, very particularly, of the type of effort made.

**Pathology**

It will suffice to examine certain special efforts to see how the muscles of the trunk (acting as levers), which enter into action, in an exclusive or predominant manner, vary for different efforts. There are different ways in which the same phenomenon of effort may be manifested, and consequently different lesions in harmony with the different kinds of effort.

But while the diversity of the different groups of muscles entering into action characterises the different particular types of effort, it does not, however, explain the lesions which sometimes result therefrom.

In effort, as in habitual work, no morbid change occurs when the muscles brought into play exercise their function in a gradual, regular and coordinating manner in consonance with the act, that is to say, in a normal functional adaptation and correspondingly equilibrium to the powers and resistances at work. If this equilibrium is broken, troubles and organic changes result when the muscular forces are brought into action hurriedly; when it is violent and sudden, or when the antagonistic muscles especially do not act in harmony and synchronously but inharmoniously and tempestuously.

This abnormal mechanism in effort may result both from general and from local effort.

**General effort** may damage the endo-thoracic, endo-abdominal and peripheral organs.

As regards the thoracic organs the damage may be done to the heart, the large blood vessels and the lungs; and as regards the abdomen all the organs therein contained, but quite especially those susceptible to a certain amount of movement. The peripheral lesions affect the muscles and parts connected with them, as well as the blood vessels.

The pathogenic effect shows itself in disturbances of the circulation or as the result of compression or in discordant muscular actions.

**Pulmonary emphysema** is the most frequent lesion in workpeople who are required to practise continual effort and where deep inspirations and energetic expirations are necessary. The effect is of slow evolution but it may show itself in an acute form, although transitorily, as, for example, after a race, or excessive exercise in fencing, etc. Emphysema shows itself by the frequent and deep respirations which have to be taken in certain set work, and which, little by little, overcome the elasticity of the lung, distort the alveoli, especially when the lung is already violently distended by a deep inspiration, or when, in the opposite case, the alveoli are still violently distended by a forced expiration (glass blowers, players of wind instruments). This is the reason why the cause of emphysema due to effort must not be attributed solely to the act of inspiration (Laennec) or of expiration (Mendelsohn, Jernner), but to both (Banti).

**Tearing of the pulmonary tissue,** of which bronchorrhoea is the specific clinical manifestation, sometimes accompanied by subcutaneous emphysema, circumscribed and diffuse, is less frequent. It occurs among workmen who have to make an effort demanding the maximum use of the upper limbs as levers with which movement the thorax also has to be associated and who must inhale and expire forcibly. The same mechanism is found among stone-breakers, miners, and woodcutters, who handle heavy...
weights in movements with a wide sweep. It cannot be doubted that changes in the pulmonary circulation constitute a factor which comes into play in causing this lesion, although other factors may intervene, inherent in the special conditions of the subject (arterio-sclerosis, haemophilia, specific lesions, etc.).

There are even those who consider it to be a *sine qua non* for the occurrence of tearing of the pulmonary tissue that there should have been a pre-existing lesion capable of acting as the point of least resistance. But this fact above all depends on mechanical principles and is due to the manner in which the inspiratory and expiratory muscles act on the lung which happens to be in a particular condition. The phenomenon really occurs when the lung, in a state of the greatest expansion after having stored up the maximum quantity of air, with the glottis closed, is subjected (at the moment when the phase of pre-effort passes into that of post-effort) to the brusque and violent action of the expiratory chest muscles, as, for example, at the moment when the arms of the woodcutter bring down the axe rapidly and with an effort. The concentric movement of the thoracic cage does not allow of an equally, rapid yielding of the pulmonary tissue, which flattens itself violently *en bloc* and bruises itself as if the thorax and its contents were tightly squeezed within a circle. In this mechanical position the parenchymatous tearing occurs generally near the apex, where the lung presents less resistance, and the more readily does it do so when the lung is in a condition of the greatest saturation with blood and no longer in a spongy and elastic state, but of a consistency similar to that of the spleen or kidney (Gosselin). Mori has described a case of pulmonary tearing accompanied by slight bronchorrhagia and subcutaneous emphysema extending to the neck, the shoulder, the region of the pectoralis major, in a blast furnace worker who with two mates had broken the pigs of iron with a heavy steel club. One almost exactly similar case (except that it was fatal) has been described in a young healthy workman who made a very great effort to stop a heavy body from falling on him.

The heart can show injurious effects, as the result of physical effort, both in regard to the muscle fibre as well as the valves.

Acute dilatation of the heart has been recognised from of old as a result of data and from clinical experience. Recently this morbid condition has been denied by some authorities, more especially after radiological examination. It has only been admitted for subjects
presenting active myocardial degeneration, while others consider it possible even among healthy persons. The latest radiological studies show that the normal heart, during physical effort, does not undergo any distension of its muscular walls, but, on the contrary, a marked contraction in volume almost instantaneous, proportional to the intensity of the effort and to the trained condition of the subject. It is even admitted that an acute dilatation of the heart can occur among subjects with myocardial degeneration or with valvular lesions even when well compensated. Nevertheless, as a secondary myocardial hypertrophy can be developed as a result of continuous occupational strain which is an indication of too great functional activity of the heart while at work, it can, under exceptional circumstances, constitute an acute form of dilatation due to efforts of very great intensity — as observed by Coutin and Foville in singers and players of wind instruments.

According to the classical view of effort, the blood, thrown out of the pulmonary circulation during deep expiration by the contraction of all the respiratory muscles, would appear to overload the systemic circulation and consequently exercise an extraordinary and sudden pressure on the walls of the left ventricle; hence a distension of this proportional to the effort and to the peripheral endo-vascular resistance; the myocardium having passed the maximum limit of its elasticity, would be able to produce arrest of the heart and sudden death.

Other authorities are of opinion that the cause of fainting is to be found in excessive pressure of the blood in the pulmonary circulation; in this case it would be the right side of the heart which would be at fault.

While admitting that the heart of normal individuals during effort undergoes a reduction in volume, not by a mechanical effect of increase in endo-thoracic pressure, nor by anything wrong with the circulation of the blood, but rather by an increase in the muscular tone of the heart, that is to say, by a state of cardiomyotony occurring at the same time that the contraction of the voluntary muscles does, it must be remembered that the opposite phenomenon of cardiac dilatation should be confirmed by a hypotonic state when, by excessive effort or the state of the myocardial fibre, the limit of physiological reserve has been passed. As cardiomyotony is also found during hard work (Luciani, Mosso), the constitution of the slow per-
the muscles which enter into play after a certain effort and according to the position assumed by the body of the subject.

Medical literature mentions important cases of contusion and laceration from effort of the liver, kidney and spleen with laceration of the stomach and intestines (Moritz, Sterling, Grossmann, Bonome). At the same time, although such occurrences cannot be denied absolutely, they can only be accepted with great reservation and after severe criticism. The increase in the endo-abdominal pressure during effort, admitted on theoretical grounds and confirmed by Pieraccini's experiments, easily explains the displacement of certain movable endocavitary viscera — intestines, uterus, kidney, spleen and liver — as a rare event, under the pressure exerted by the muscles of the abdominal walls and by the diaphragm itself which becomes depressed while the reflex effort is taking place. The diversity of the viscera susceptible to injurious effect during effort is related to the kind and intensity of the effort and to the position in which the subject finds himself when the effort is made. Thus, for example, in a lying down position in a woman the abdominal pressure is scarcely 15 cm. of a column of water, whereas in an upright position it is about 40 cm. The pressure varies in the different parts of the abdominal cavity according to the different positions assumed by the individual and with the weight of the organs which weigh upon it (Kelling, Harmann).

In the production of prolapse of the uterus the action of mechanical effort in raising weights and excessive fatigue from occupations demanding long standing is admitted by all gynaecologists; but the effect is slow in showing itself. Nevertheless, some cases lead to the conclusion of the possibility of an acute form.

It would perhaps be more logical to admit that violent effort is the only way of bringing into evidence a pre-existing morbid condition; as is shown especially in the production of hernia, in which effort, often looked upon as the direct and immediate cause, really only represents the chance moment for converting a latent pathological fact into a potential condition.

In passing, mention should be made of other visceral lesions which have been attributed to violent effort of the abdominal walls such as appendicitis, and orchitis, while observing merely that their pathological interpretation is still much in dispute.

Recently (1927) Pasteur, Valery-Radot, Carrié, Blamoutier, and Laudat have described a case where urticaria was accompanied not only by violent humoral trouble but by clinical manifestations of the most pronounced character recalling the symptoms shown by an animal when suffering from severe anaphylactic shock. Study of this case shows the considerable humoral disturbances which simple physical effort may bring about in a colloido classic man.

As violent physical effort can set up slight but undoubted vascular changes, it is understandable that the same effort in a colloido classic man, the descendant, as in the case in question, of a family of asthmatics, exaggerates these humoral disturbances, and sets up an urticarial crisis with general symptoms.

The lesions of the peripheral parts of the body in generalised effort affect the muscles and the blood vessels. The pathogenesis of these changes, showing themselves in a gradual distension of the walls — ectasis — in efforts repeated over a lengthy period and sometimes in a rupture, is due to the general increase in pressure of the general arterial circulation and venous stasis. During effort and in the pre-effort phase not only does swelling of the superficial veins of the head, neck,
face and of the two jugular veins take place, with accompanying endocranial stasis, but also an increase in pressure of all the veins of the body proportional to the effort made, as Delhez has shown by direct manometry. The stasis is partly due to suspension of the respiratory act favouring a backward circulation, and in large measure to the pressure exerted by the abdominal muscles in the act of contraction upon the viscera and abdominal veins. Hence, less venous blood from the inferior vena cava, reach the right auricle. Fig. 84, which is that of a glass blower, shows well the venous stasis not only of the jugular vein and frontal veins, but also those of the arms, the forearm and of the hand. During effort the blood pressure of the great arterial circulation increases also according to some, but is denied by others who believe there is even a marked diminution. The blood stagnation explains the formation and aggravation of varicose veins and varicocele, as well as the rupture of veins, already weakened, whilst the increase of the arterial pressure explains the bursting of aneurysms and occurrence of cerebral apoplexy under the action of a violent effort.

Localised effort in which a group or several muscle groups of a given area enter into activity to carry out a particular piece of work can be represented by a contraction which, in its intensity and duration, exceeds the limits of normal function.

The effort in its intensity can be represented: by an exaggeration of the muscular tone — hypertony; by an excessive distension of the fibres — hypertracction; by a movement which exceeds the normal degree in which it ought to be done — hyperkinesia.

In certain efforts, as in squeezing a dynamometer, in carrying a heavy weight by hand and with arms stretched parallel with the body, there is hypertony. Hypertracction comes in when movement is accomplished in stretching the muscles to more than their normal limit (lifting down an object which is placed rather high, while holding the trunk taut). In the first case the muscle is seized with a disagreeable sensation analogous to cramp, and, further, a feeling of fatigue is felt which soon passes off. The same sensations occur in the movement accompanying hypertracction. Tearing of the muscle fibres may be produced when the movement is passive, as is the case when a joint of a workman is caught in a machine. The effects of a hyperkinesic movement are very like those experienced in hypertracction.

Absolutely injurious effects are present in a dyskinetic effort, that is to say, one where the antagonistic muscles do not enter into activity synchronously as an alternating phase, and when the combined motions in successive moments of time which are necessary to enable the muscular forces to act harmoniously in the accomplishment of their task, are lacking. The muscular lesion always affects one or several muscles in contraction when they are surprised by a sharp movement of the antagonistic muscle group coming into play before they have been able to recover their elasticity, or when an external force — e.g. resistance due to a heavy weight — exceeds the tonic state of the muscles. Then the rigid contracted muscle — which has thus almost lost the character of its elasticity — undergoes "a distension with effects varying according to the active antagonistic force — muscular force or external resistance — and in inverse ratio to its resistance.

What happens as the result of an unco-ordinated movement resulting from lack of synchronism of the muscular activity is observed automatically among motorists. To set an internal-combustion engine going, the driver turns the crank in the direction of the hands of a watch. Under normal conditions the engine thus set in motion goes off regularly in the direction of the rotation of the handle which disengages itself automatically without the slightest inconvenience. On the other hand, it may happen that the sparking of the motor is set going before the piston has finished its work of compression. Under these circumstances the explosion forces the piston in the direction contrary to the direction of the hand cranking and the crank thus receives a strong and sudden counter-coup, with a violent repercussion on the wrist of the driver, who in slight cases receives the sensation "of a nasty knock from a stick" (in the words of a motorist) as a consequence of muscular distension; but on a serious occasion the motorist may be the victim of an epiphyseal fracture of the radius — the characteristic Colles fracture.

As a consequence of the procedure described a simple muscular distension — this is the commonest case — may take place, characterised by a violent pain passing away quickly with immediate resumption of function, attributable, some authorities believe, to slight tearing of the muscles fibres, and according to Mori, to an exaggerated traction on the nerve fibres. In lesions of the second degree, a tearing
of the muscular fibres occurs and sometimes, given the resistance offered by these, epiphysial detachment at their point of insertion, and, more rarely, a fracture. Muscular lacerations are not rare—especially those of the biceps of the arm and the quadriceps femoris. Thus instances are described of rupture by muscular contraction of the coracoid process of the anterior tuberosity of the tibia, and of the tuberosity of the calcaneum. Mori has even observed a case of detachment of a small lamina of bone from the calcaneum at the point of insertion of the tendo Achilles. He has also seen fracture of the right humerus in a footballer, due to a sudden movement of abduction of the joint to reach the ball.

Muscular hernia is also due to laceration of the external aponeurosis as in one of Mori’s cases (fig. 85). It can also be the consequence of a violent, sudden movement of a muscle during its contraction not accompanied synchronously by stretching of the sheath. Excessive effort and strain, by the slow and sudden lesions which they can induce in workpeople, certainly merit some mention relative to the subject of prevention and legislation against accidents. Yet the space allowed for this article does not permit of it, so it must suffice to say merely that the lesions produced slowly as the result of efforts made during arduous and continuous operations come within the scope of industrial diseases, while those of acute onset due to violence encountered at work come within the scope of accidents. As such, they come under statutory requirements as to compensation.

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**Electric Lamps**


When an element of a galvanic pile or a dynamo machine produces a difference of potential in a circuit the electrons are set in motion and the circuit becomes the seat of an electric current. Ohm’s law shows the relation existing between the electro-motive forces (or difference of potential E, the intensity I of the current, and the resistance R of the conductor). This relation is expressed by $E=I\times R$ where E is in volts, I in amperes, and R in ohms. There is thus a fall in potential proportional to the resistance which separates the two points under review. The energy thus lost by the electric current is converted into heat and heats the conductor. If the conductor is sufficiently long and thin it can be brought to incandescence and gives out radiant energy.

The object of the manufacture of incandescent lamps is thus to obtain an apparatus converting the greatest possible part...
of the electric current into radiant energy and emitting the largest number of rays to which the eye is sensitive. As the quantity of energy given out varies according to the square of the absolute temperature, the temperature must be considerable; this necessitates having a filament not easily fusible.

**PROCESSES OF MANUFACTURE**

Tungsten is the most suitable material both in regard to fusion point and required radiation; but even with this substance the fraction of electric energy converted into light is minimal.

The luminous intensity of a lamp is determined by means of a conventional standard, that is, by means of a light of known intensity with which the light in question is compared. The standard varies from one country to another.

The raw material is trioxide of tungsten or tungstic acid, a yellow powder obtained from treatment of the ore. Tungsten itself is obtained by reducing the tungstic acid in an electric furnace at a temperature of 1,100° to 1,200° C. in an atmosphere of hydrogen. The tungsten thus obtained is in the form of a coarse powder.

When the incandescent lamp factories buy unpurified tungsten they must rid it of its impurities: arsenic, phosphorus, and iron. The arsenic and the phosphorus are eliminated by the magnesia mixture, the iron by ammonia, and the molybdenum by evaporation with concentrated sulphuric acid.

The filament is nearly always obtained by mechanical treatment. The powdered tungsten is first subjected to a pressure of 5,000 kg. to the square cm., converting it into a small stick of 1 sq. cm. in section and 10 cm. long. To make the stick, which is still very fragile, more consistent it is heated to near its melting point by passing through it a current of 15 volts and 3,000 ampères. It is then introduced into a hammering machine working at great speed which reduces the diameter of the stick to 1 sq. mm.

A process similar to wine-drawing through a great number of diamond shaped orifices with steadily diminishing diameter ensues, until the threads are reduced to a thickness of 0.02 mm. Lubrication is effected by means of colloidal graphite in suspension in water and sulphur or organic derivatives of tungsten in a colloidal state. The thread is calibrated by weighing in a torsion balance a fixed length of thread.

Before being mounted in the lamp the filament requires to be freed of the substances with which it is impregnated. To do this it is placed in a tube containing a mixture of hydrogen and nitrogen and is brought to incandescence by the passage through it of an electric current.

The preparation is still, though much more rarely, done by another method, namely, by making a paste of tungsten with an organic binder. Nitrate of thorium is added and the whole brought to a temperature of 300°-400° C. which converts the nitrate into oxide. Reduction is then effected in a current of hydrogen, but the oxide of thorium is not reduced. The paste is then made into a filament by squirting through a die, and is further submitted to an electric current so regulated that the temperature rises progressively. The structure of the filament thus becomes crystalline. The Pintsch method allows of the production of a filament of a single, flexible crystal by suitably regulating the temperature.

The filaments thus obtained can then be subjected to mechanical treatment in the cold without breaking up. In the processes above-mentioned, contacts of mercury are used to bring the heating current to the thread.

The bulbs made in the glass-works (see article "Glass Industry") are made of glass containing a large proportion of red lead and are provided with a sufficiently long neck. They are first cleaned with dilute acid, then the neck is cut to the desired length (fig. 86). A small hole is then made at the top of the neck of the bulb, and a small tube or "stem" is fixed to create the vacuum, once the lamp is mounted. This operation is generally done by machine.

The base of the mount consists of a little tube of glass, flanged (fig. 87) so as to attach it to the neck of the bulb. The glass rod on the other hand, is cut to the desired length as a support and is provided with two little flanges (fig. 87). All these operations are effected by rotating machines which comprise numerous gas jets.

The little flanges are heated until they are softened by a blow pipe flame and to them the supporting wires are then attached. The lower wires are of iron or nickel while the upper ones are of the molybdenum; they must be elastic because the filament becomes shorter with usage. The leading-in wires are made of copper or nickel-iron except the portion embedded in the glass, which is made of platinum, for it is necessary at this spot to avoid possibility of entry of air, as a metal is required which will not get covered...
with oxide, and having a co-efficient of expansion near that of glass.

The different parts of the leading-in wires are welded together by the blow-pipe or by means of an electric arc. This work requires both skill and good eyesight. The supporting stem, the leading-in wires and the flange tube are thereafter arranged as shown in fig. 87, then introduced into a machine where the top of the tube is heated until it is soft by a blow-pipe flame and then pressed on to the base of the stem. The two pieces become thus welded together while the leading-in wires are partly embedded in the glass (fig. 88).

The final shape, however, is given to the tungsten filament by placing it in a gauge; then raising it to a temperature of 1,000°-1,200° C. in neutral atmosphere in order to make it keep its form.

Finally it is placed in position on the supporting wires and the two ends are fixed in the folded back extremities of the leading-in wires, in order to ensure a good contact (fig. 88).

The bulb into which the mount has been introduced is heated at the point a-b (fig. 86), then elongated; the little tube which now serves as the base of the support has its flanged end welded to the narrowed portion of the neck, the lower part of this is cut off and thrown away. All these operations are done generally in a single machine.

The bulb now is closed (fig. 88), and does not communicate with the atmosphere except through the exhaust tube.

The lamps must have the air very carefully removed so that the filament does not burn in atmospheric air.

They are, therefore, placed in communication by means of the exhaust tube with pneumatic pumps, which require to be sufficiently powerful as many lamps are treated at one and the same time.

Mercury vapour pumps were formerly exclusively used; they are now for the most part replaced by oil pumps. Gaede's diffusion apparatus, into which the air is drawn by the mercury vapour, is still used, but only for special lamps.

To facilitate the creation of the
vacuum the lamps during the process are heated to 460° C. The vacuum obtained is determined by means of the MacLeod gauge, an apparatus containing mercury.

These apparatus not infrequently break, as some portions of them consist of glass or porcelain and the mercury escapes on to the floor. The workpeople also come into contact with mercury, not only in filling them, but also in collecting the spilt mercury, or again when they have to filter and purify the mercury after use. The danger is increased the higher the temperature of the workroom. When the vacuum is completed the lamp is closed by melting the exhaust tube with the blow-pipe flame (fig. 88).

Lamps Filled with Gas

A little air always remains clinging to the sides of the lamp and in the filament, the presence of which causes gradual deterioration and produces a blackish deposit on the internal surface of the bulb which interferes with brightness. In order to overcome this disadvantage lamps are now made which, after the vacuum has been created, are filled with a gas.

The gas most frequently used is argon, which is taken from liquid air. But it still contains a little nitrogen, oxygen, and oxidised substances which are got rid of by burning with hydrogen and then passing it through a heated tube containing copper and oxide of copper. The gas is then carefully dried with sulphuric acid, chloride of calcium or phosphorus pentoxide. Sometimes instead of argon a mixture of argon and nitrogen is used.

Half-Watt Lamps

The yield of the lamps may be improved (to the extent of about one candle-power per half-watt) by using a spiral thread in place of a simple filament. Half-watt lamps are usually filled with argon.

Attachment of the Cap

The cap is cemented to the lamp, and the leading-in wires are welded, the one to the ribbed portion of the cap, the other to an insulated plate (Edison cap) (fig. 88). A tin solder containing lead is used.

As for the cement, that consists of lime or gypsum mixed with alcohol; in order to harden it rapidly the lamps only require to be heated.

Testing the Lamps

The lamps are subjected to a current the tension of which is 10 per cent. greater than that which they are likely to encounter; they are then examined before an opaque glass to detect flaws in the manufacture. The glasses are next etched with the maker's name, the candle power, etc., by means of a liquid containing hydrofluoric acid. The lamps are sometimes rendered opaque with dilute solutions of hydrofluoric acid.

Compressed Air Cylinders

Incandescent electric lamp factories always have a considerable stock of steel cylinders containing compressed hydrogen or nitrogen. Most States have laid down regulations as to the quality of the gas, and the method of closing the cylinders, in order to prevent explosion during manipulation. International regulations on this point are under consideration.

The cylinders — Mannesmann cylinders, weighing 40-50 kg. and capable of containing 40 litres of gas at 150 atmospheres — are kept on wooden stands in a special place. Chains attached to them prevent them from falling. They are placed in communication with pipes bringing the gas into the workroom. In order to avoid the risk of explosion no electric interrupter must be present in the depot for the cylinders. The roof of the place may be watered in case of great heat or fire.

Pathology — Hygiene

The manufacture of the incandescent lamps causes very little muscular fatigue among the women workers (hardly any men are employed) as will be understood from the description given above and as will be confirmed by visiting such a factory.

The workers remain seated or standing at the same spot most of the time and any distress is due more to small movements than to energetic ones.

Apart from the possibility of explosion (now very rare) of the compressed gas cylinders, due to faulty closing, etc., accidents arise solely from the breakage of the glass bulbs when they are handled carelessly.

Such breakage is fairly frequent and often the presence in the air of a fine glass powder can be detected (Kranenburg).

The state of the atmosphere, particularly, may be injurious on account of
the numerous gas jets in the workrooms which use up the air, and, in the summer especially, may cause it to reach an uncomfortable temperature. Neither are the products of combustion of the gas in themselves quite harmless. But although the exhaustion of the atmosphere cannot be altogether avoided, the products of combustion can be got rid of easily enough so as to prevent injury to the workers: all that is necessary is to install hoods connected to efficient exhaust systems.

From a hygienic point of view processes should be made, as far as possible, automatic, because the worker comes much less into contact with the gas when it is only necessary for her to place the articles in a machine.

It would certainly be interesting to determine definitely whether the close examination of the fine filaments requiring, as it does, strong accommodation induces or aggravates eye troubles (myopia, accommodation, etc.) and temporarily unfit the workers for their task. This work demands a strain on the ocular function; undoubtedly sets up a certain amount of ocular fatigue and renders rest periods necessary, e.g. five minutes every half hour. The workers carrying out the first testing of the lamps (illumination under a higher pressure) should wear dark goggles or work before an apparatus provided with a special screen to protect the eye against the full glare of the source of illumination.

Mounting also requires close attention, and may set up fatigue more readily than other jobs. Teleky in 1911 described an occupation of workers engaged in making incandescent electric bulbs, one which is not however of very frequent occurrence. This is a motor affection of the muscles of the ulnary side of the forearm and little finger accompanied by tingling and numbness along the course of the ulnar side of the forearm.

It should be said that most of the women affected were pregnant and cessation of work eased the trouble. The muscles supplied by the ulnary nerve were more or less atrophied, particularly those of the little finger. One case was that of a woman who had been employed for less than two weeks. The persons who were employed in the delicate work of inserting the blow-pipe, but exhaust ventilation installed for the removal of the gas fumes generally should have excluded any chance of poisoning. Nor could there be any question of muscular fatigue because the nerves were not affected. The probability is—and this has been confirmed by observation—that certain parts of the ulnar were subjected to pressure because the elbow in two cases and the ulnar side of the forearm (in the others) rested on the edge of the table. This explains the rarity of the affection.

Sternberg, however, thinks these lesions may be fairly frequent as the ulnar is easily vulnerable. But conditions for their production are rather special. Pach (1913) has also reported similar cases. Whatever be the truth, their causes can be easily avoided if a little attention be paid at the onset, especially as soon as paresthesia appears.

More serious illness may occur if, as the result of breakage of the apparatus containing the mercury, the workers are exposed to inhalation of mercurial vapour. These breakages are fairly frequent and vapourisation is favoured by the high temperature customary in the workrooms. The number of slight or moderate cases of mercurialism is therefore by no means negligible.

The best way of avoiding this form of poisoning would be to substitute methods which do not employ mercury, or to install means for preventing the scattering of mercury when the capillary tubes break; the mercury too that has been spilt must be rapidly and carefully collected. Mercurial poisoning, practically speaking, cannot occur during the soldering operation.

Mention might also be made of the respiratory troubles which may be set up by inhalation of the vapours of ether, amyl acetate, nitric acid (nitrous fumes), and hydrofluoric acid, and of the cutaneous lesions due to contact with these acids or ammonium chloride (used, e.g., in Russia as a mordant for the metal before stamping the lamp).

Reinberg and Kupritz (1926) have studied the specific lesions which the persons engaged in the manufacture of Röntgen tubes at Leningrad suffer from. (See article “Röntgen Ray Operators”.)

Finally, according to a recent study (1924) certain Russian factories make use of a mastic made with phosphorus to make sure of airtightness either of the “exhaust tube” when this is placed in communication with the pneumatic pump, or of the glass base of the support (mounting). It would appear that no case of phosphorous poisoning has been reported up to the present in the factories.
descent electric lamps would be difficult to draw up. Bender however lays stress on the following: the temperature should never, on even the hottest days, exceed 25° C.; ventilation and temperature should go hand in hand; the relative humidity to be kept below 50 per cent. and the proportion of carbonic acid gas below 30 parts per 10,000.

Cubic space per person should be at least 15 metres per person and the air should be renewed at least three times an hour. The minimum height of workrooms should be 4½ metres.

Hoods connected up with effective exhaust fans should be placed over every apparatus utilising naked gas jets.

Attention should be directed also to the point that clothing worn in the workrooms should be suitable for work carried on in a heated atmosphere.

LEGISLATION

In the Netherlands statutory notification is required of mercury poisoning, inflammation of the joints, and sub-cutaneous cellulitis, as well as ulceration of the cornea and conjunctiva in persons employed in incandescent electric lamp factories.

Employment of women and children in those parts of the factory where there is risk of poisoning is minimally brought under the recognised regulations. Similarly, cases of poisoning due to mercury vapour from the mercurial pumps are brought under the Workmen’s Compensation Acts in those countries where industrial diseases are included as coming within this Act. Such cases are included in the list adopted at the Sixth Session of the International Labour Conference (Geneva, 1925).

Compensation, however, for mercurial poisoning is not granted to persons employed in incandescent electric lamp factories in Western Australia, although compensation is granted for eczematous ulceration of the skin and ulceration of the nasal and buccal mucous membrane when set up by asphalt.

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Electrical Apparatus

French: Electrique industrielle (appareillage, installation, etc.); German: Industrielle Elektrizität (Apparate, Einrichtung); Italian: Elettricità industriale (apparecchi, impianti); Spanish: Electricidad industrial (montaje, instalación).

TECHNICAL DATA

The materials used for the construction of electrical apparatus are (a) good conductors and (b) good insulators.

(a) The conductors most used are copper and carbon. Copper, which must be particularly pure, is obtained by refining raw copper by the electrolytic process (see article "Copper"). It is drawn out into wire, or shaped into bars and strips, when conductors for carrying heavy currents are required, such as conductors for electric furnaces, or it is turned for making terminals, or various parts.

The different kinds of carbon used in electrotechnique are: anthracite, which is used in the manufacture of brushes for dynamos and for motors; anthracite coke, which is used for electrodes and the carbon plates of batteries; retort coke, the uses of which are very varied and very important; petroleum coke, which often replaces retort coke; soot, which is compressed to make pencils for arc lamps; pitch and tar, which are usually used alone, or may be combined to serve as a mixing agent for the preparation of the pastes of which dynamo brushes, electrodes and microphone carbons are made.

As a rule, articles moulded in carbon are simply composed of a mixture of carbon and tar. Sometimes, especially in the case of pencils for arc lamps, mineral substances, intended to increase the luminous intensity or the conductivity, are also added; such as cerium oxide, fluoride of calcium or strontium, soluble silicates, alkaline phosphates or borates, potassium chloride and salt petre. For dynamo brushes copper is incorporated with the mass of carbon in the form of powder, wires, or thin sheets. The mixing, casting and firing are done as for electrodes (see later). Iron and bronze have also been used in the manufacture of telegraph wires. Lastly, other conductors are used for the construction of apparatus, but much more rarely; such as aluminium, aluminium bronze, silver and certain alloys, which are used for calibrated resistances and contain nickel, chromium, manganese, nickel-chromium and "manganin".

A great many switches and measuring instruments are of brass and it is not unusual for contact to be obtained by means of cups of mercury.

(b) Insulators are also very numerous. They are divided into rigid and pliable insulators. The former are used in making supports for apparatus; they include ebonite, marble, bakelite, slate, glass, porcelain, asphalt, paraffin wax and wood.
There is a tendency to substitute for the above various products, such as steatite, which is derived from talc, asbestos sheets and naphthalene or compressed mica. Pliable insulators are used for making the insulating covering of wire. For this purpose gutta-percha, india-rubber, impregnated jute and impregnated paper are used. Gutta-percha is the best insulator of all, but its price is somewhat high. It is used alone, after it has been softened by heating, or mixed with resin and tar; this mixture is called "Chatterton’s Compound".

India-rubber is most generally used. An insulating layer of this substance must be placed on the conductor before vulcanisation. When gutta-percha is used for insulating wire, the wire is simply passed through a chamber in which the copper wire passes. The enamel mixture is applied, which the copper wire passes. The enamel mixture is then passed through a drum where the enamel is applied by adherence. The wire then passes into a machine which contains also two ribbons of india-rubber wound on reels. These two ribbons are placed along the wire, one above and one below; the whole then passes into the opening of two tangent pulleys turning in opposite directions. The ribbons are thus applied to the wire and form an insulating sheath round it. Next it is vulcanised.

Flexible wire is formed by a certain number of fine wires which are twisted together by machinery and are then insulated.

Enamelled wire is used for small work and for winding motors and generators. Enamel with a base of bitumen dissolved in benzene or spirit of turpentine is no longer much used. It has been replaced almost everywhere by a mixture of vegetable oils for varnishing, and of gum.

The mixture with the addition of a solvent is kept at 30°-50° C. in a tank through which the copper wire passes. The enamel is applied by adherence. The wire then passes into a small vertical furnace where the enamel is fired at 200° C. The operation has to be repeated several times; the fumes which form in the furnace and the products of combustion are removed by an exhaust placed at the upper part of the furnace. Branch wires are insulated by one or several layers of india-rubber, then covered again with india-rubber tape wound round in spirals to form another covering. Vulcanisation is then carried out on drums by winding the wire in closely touching spirals; the linen of the tape prevents sticking. Piston machines (daubers) similar to those used for gutta-percha are also used for covering the wire with an insulating sheath protective cover. The compression chamber of the first of these machines contains the india-rubber intended to form the insulating layer. Into the second machine felt is introduced, a mixture of india-rubber, vegetable fibres and mineral matter prepared beforehand in special grinding machines. The wire is then covered with a protective sheath.

In the modern construction of electrical machines, mass production has naturally been introduced. When machining iron plates, their insulation may be effected by means of paper pasted on to the plates by machinery, or by varnish which dries in the air or, on baking, in a stove, or by using for insulation the oxide which forms on the iron plate in the process of annealing.
The cutting of iron plates for electric machines is done on high-speed notching machines or by the aid of multiple punches.

Some manufacturers anneal the iron plates after cutting. Then follows testing and a slight fettling which is sometimes done by a sand blast.

Winding by hand is replaced to-day by winding on a gauge. It is not necessary to enter here into further details on the winding of different machines, on the winding of inductors, on machining collectors and on mechanical machining.

Reference need only be made to the operations of stoving and impregnation with varnish, and to the fact that the insulating varnishes used in the manufacture of electric machines are chiefly thick varnishes, such as oils and various resins, with the addition of various solvents, applied with a fine brush or by dusting or by immersion followed by drying in a stove, or, more recently, by the process of drying with impregnation in vacuo; or compound varnishes with a base of pitch and mineral oils; or synthetic resins, open products derived from formol and phenol. The resin most used is bakelite in the A state, dissolved in alcohol; the solvent is impregnated, extracted and polymerised (see article "Bakelite").

In the manufacture of electric cables, vulcanised india-rubber was used in the early days as insulator, and sometimes gutta-percha. India-rubber was later replaced by textile materials, particularly by jute, impregnated with hydrocarbons, such as ceresine and resin, with the addition of fatty materials, the impregnated cable being put in a sheath of lead.

Simple conductors insulated by paper, for which each manufacturer has a method more or less his own, are wound together and made into a thick cord on a special machine for making a compact cable of perfectly round form. The empty spaces are filled by stuffing, formed of small cords of paper and jute strongly compressed.

In some cases other small bands of paper are wrapped round the new cable. Insulation by dry paper is a purely mechanical process of manufacture. The cables are then dried, impregnated to saturation and encased in lead.

With this object, they are placed in baskets or hampers or on metallic drums and enclosed in autoclaves heated by steam. When the drying, effected by means of vacuum, and as complete as possible, is finished, the tank is filled with some hydrocarbon impregnating material. The lead sheathing is done by means of a lead press, which as a matter of fact is a press for making lead pipes. The covering may be very loose, without being fastened, as in the case of telephone cables, with air circulation, or very lightly fastened, as for cables encased in india-rubber, or fastened to any degree that may be required, as for cables with impregnated paper.

Cables with a lead sheath may be protected by a covering, the composition of which varies according to use, and may be either cordage, asphalt, steel ribbons or watertight materials.

The cables are then subjected to tests for watertightness, and for insulation, capacity and rigidity.

**Electrodes**

Carbon electrodes are the most common; they are used especially for electro-thermal apparatus, such as electric furnaces for metals or carbide of calcium. Various kinds of carbon are used (see above), which are mixed with tar or pitch and changed into graphite by heat. The preparation of the paste is carried out in apparatus similar to the mechanical kneading troughs of bakers. It is sometimes first mixed with a little water, then tar is added which eliminates the water. Some factories adopt a process with several calcinations, each followed by grinding and fresh mixing with tar. The paste is moulded in a hydraulic press, and then baked at a red heat in a gas or electric furnace. Electric arc furnaces, in which the materials to be heated act themselves as the electrodes, are preferred nowadays.

Acheson prepared graphite by passing a very intense electric current into mixtures of coke, petrol, pitch and silica or oxide of iron.

After heating, the electrodes are scraped or sharpened by means of grindstones, or drilled to take metal fittings. For some special uses they are covered with a layer of oxide of aluminium, carborundum or magnetite.

The use of the continuous electrode, not subjected to firing before use, tends to become more general in the case of the electric furnace; the mixture of coke and tar is introduced into a cylindrical sleeve made of sheet iron, which is placed above the furnace; by degrees as the electrode is used up the large sausage-shaped mass of paste is forced down, and, under the influence of the heat of the furnace, becomes changed into graphite. This process does away with the necessity for stopping the furnaces to replace the electrodes.

Industries based on the electrolysis of melted salts (see article "Aluminium") or of saline solutions (see articles "Electroplating" and "Chlorine") use electrodes made of the most varied materials; carbon, iron and platinum are most used.

Mercury is used as a mobile cathode in the electrolysis of solutions of sodium chloride in the preparation of caustic soda and chlorine according to the Solvay process. The use of lead is unusual except for accumulators (see that article).

The negative electrodes of Leclanché cells are of amalgamated zinc, so that the battery only acts when the circuit is closed. The zinc is first of all cleaned with sulphuric acid, then the electrodes are plunged into mercury or into a bath of mercury dissolved in nitric or hydrochloric acid.
**Tubes with Incandescent Cathode (X-Ray Tubes, Kénontron Rectifiers, etc.)**

The technique is similar to that of the manufacture of incandescent lamps (see article "Incandescent Mantles"). The principal danger arises from breaking of the mercury pumps. Various parts of tubes with incandescent cathodes are of molybdenum or of tungsten.

**Sources of Danger**

The dangers to which workmen are exposed are represented by exposure to dust, particularly dust of such metals as copper, brass and lead, while shaping or polishing the parts; to ebonite dust; to nitrous fumes during scraping or cleaning with nitric acid; to mercury fumes from solvents in the manufacture of electrodes; from electric currents and burns.

The injurious effect of the temperature of workrooms must again be pointed out, where the degree of humidity is also high. In certain factories high incidence of infections, following pricks caused by copper wire, has been observed (McGowan).

In a Russian central electric station, Grigoriev (1925) investigated the quantity of sulphur dioxide which was given off in the boiler-house. The analysis, repeated during two years, proved that the average had been reduced at least five times, for it had passed from 0.270 and, according to the season, 0.380 to 0.050 and 0.080.

**Statistics**

Statistics are not numerous; they deal specially with accumulator works (see article "Accumulators").

In Great Britain from May 1899 to 1918, out of 208 cases of mercurialism, 24 occurred among makers of electric meters; in 1920 another case was reported in this industry, and a second affecting a fitter of electrical apparatus; in 1926 in Prussia a case of mercurialism was caused by mercury spilled on the floor of an electro-technical laboratory. The sickness statistics of Leipzig relating to a group of less than 5,000 members employed in the manufacture and installation of electrical apparatus give the following morbidity and mortality figures, as compared with the number of cases among 100 workers in all occupations per annum taken as unity: for all sickness, 0.8; deaths, 0.8; infectious diseases, 0.9 (of which tuberculosis, 0.9); nervous diseases, 1; diseases of circulation, 0.9; of digestion, 0.7; of respiratory organs, 0.9; of the skin, 0.5; of the locomotor apparatus, 0.5; and accidents, 0.9.

In Austria a case came to light in 1921 in a nitric acid factory.

In the United States a case was reported by Edsall Sappington in 1924 who recorded the results of investigations made during five years on the frequency of diseases and accidents among the personnel of the Edison Electric Illuminating Company of Boston. It was very difficult to obtain accurate information on the causes of absence from sickness. However, from 1918 to 1922 the author found the following rates per 100 employed: 47 due to colds; 32 to dyspepsia; 11 to disorders of the digestion; 9 to pharyngitis and tonsillitis; 6 to nervous diseases; 5 to rheumatism; and 18 to all diseases. The highest rate was found among women. (For fuller details see the original article.)

Brundage also has reported the causes of absence found during ten years among the personnel of the Edison Electric Illuminating Company of Boston which employed in 1923 2,223 men and 546 women; 79.7 per cent. of the men were between the ages of under twenty and forty-four years; and 14 between ages forty-five and fifty-four; 70.8 per cent. of the women between under twenty and twenty-nine years; and 15.2 between thirty and thirty-nine.

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The causes of sickness and accident were carefully examined and the author deduced the following conclusions:

1. Sickness rates covering the shorter illnesses, i.e. those lasting less than six or seven working days, computed from records of absence among persons whose pay is continued during sickness are not comparable with sickness rates covering the shorter disabilities among wage earners who lose their pay when incapacitated by illness.

2. As regards age distribution, the proportion of sickness was very much higher amongst young workers and especially amongst the women.

3. The toll of sickness and accidents during the ten years reviewed was equivalent to an annual experience of 8.9 calendar days of disability per male, and 14.8 calendar days of disability per female on the pay roll.

In Germany Teleky has reported a case of mercurialism in a workman employed in making electrodes; some fatal cases from electric shock have been observed among fitters of electrical apparatus; in 1926 in Prussia a case of mercurialism was caused by mercury spilled on the floor of an electro-technical laboratory. The sickness statistics of Leipzig relating to a group of less than 5,000 members employed in the manufacture and installation of electrical apparatus give the following morbidity and mortality figures, as compared with the number of cases among 100 workers in all occupations per annum taken as unity: for all sickness, 0.8; deaths, 0.8; infectious diseases, 0.9 (of which tuberculosis, 0.9); nervous diseases, 1; diseases of circulation, 0.9; of digestion, 0.7; of respiratory organs, 0.9; of the skin, 0.5; of the locomotor apparatus, 0.5; and accidents, 0.9.
4. Among the men sickness caused twelve times as many absences as industrial accidents, while among the women the ratio was 171 cases of sickness to one industrial accident.

5. Respiratory diseases caused approximately one-half of all the absences and 40 per cent. of all the time lost on account of sickness among the men. The percentages for respiratory diseases among the women were not quite so high.

6. Colds and other diseases of the nasal fossae incapacitated, on the average, 4 out of 10 men annually and 7 out of 10 women; and the days of disability were equivalent to 1.4 per year per man and 2.1 per annum per female employee.

7. There were 202 absences from sickness, exclusive of accidents, among the women to every 100 male absences, after adjusting for differences in the age distribution of the two sexes.

8. The frequency of absence for one day or longer on account of sickness decreased as age advanced among persons of either sex, but the duration of incapacity definitely increased with age, especially in the higher age groups.

As regards death and sickness due to electricity, the following information may be added to that given in the article "Electricity — Industrial Hazards Caused By". In Italy from 1908 to 1917 shocks from electrical apparatus caused the deaths of 494 persons above the age of fifteen years, giving a yearly average of 65 cases. These fatalities in 496 cases, or 67.5 per cent., were of industrial origin. An annual increase of cases during the period in question is to be noted, but the cases are to be found among persons employed in the production and distribution of electricity, in traction, and in installation work, rather than among the personnel of central generating stations. As regards deaths due to violence the group in question only figures with 1.2 per cent. of all deaths. But the death rate from shock due to electrical apparatus is 0.33 per 1,000 men above fifteen years.

In regard to occupational categories, it is found that blacksmiths, mechanics and electricians with 5.1 per 1,000, based on 228 cases, of which 225 were of industrial origin, exceed this figure; blackssmiths and unskilled workers with 1.9, based on 89 cases, 83 of which were industrial; mechanics and chauffeurs with 1.7, based on 5 cases, 4 of which were industrial; railwaymen, tram conductors with 1.4, based on 11 cases, 10 of which were industrial; engineers with 1.0, based on 4 cases, 3 of which were industrial.

In the United States during thirteen years 423 cases occurred in an electric company from electric shock, 2 of which were fatal. Women seem to be more sensitive than men (McGowan).

In Switzerland in 1920, 90 cases of electric shock were reported, 42 of which were fatal; and in 1923 60 cases, of which 28 were fatal. These cases are classified as follows:

<table>
<thead>
<tr>
<th>Type of Station</th>
<th>1920</th>
<th>1923</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generating stations</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Aerial lines</td>
<td>20</td>
<td>13</td>
</tr>
<tr>
<td>Transformers</td>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>Testing stations</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Private installations</td>
<td>19</td>
<td>6</td>
</tr>
</tbody>
</table>

It is important to note that the number of accidents (17) in 1923 due to installations of less than 250 volts is really a very large one. The accidents in generating stations occurred during operations or repairs, and it was obvious that the victim had often been disturbed when on his dangerous work.

Among the victims are found engineers and electricians 6 times; mechanics and firemen 18 times; apparatus fitters 52 times; and ordinary workmen 11 times.

L. Wyss, in his thesis (1912), emphasised the fact that the victims are chiefly young workers, who tend to be careless; these also show the highest mortality rate. The physical resistance of young, healthy and vigorous persons is, speaking generally, of no avail against the fatal effect of the electric current.

**Pathology**

The damage accrues to persons in contact with industrial electricity is directly related to the substances handled in the construction of apparatus, or set free during operations.

Thus, for example, the extremely irritating action of bakelite on the skin and mucous membranes, which gives rise to a very definite eczema, known under the name of "bakelite itch", affects persons who prepare it rather than those who use it (Hamilton). In the electro-technical section of the naval dockyards of Toulon, Bastian in 1927 noticed cases of malaise, vomiting, headache, vertigo and constipation among workers who were employed on ebonite, and especially among those who sawed and polished it. Chemical analysis of dust which was generated during these operations from two samples of ebonite, revealed the presence of 4.83 and 6.32 per cent. of lead. The evil-smelling fumes which were given off contained sulphuretted hydrogen, and, to a lesser degree, seleniuretted hydrogen and mercaptan. A third quality ebonite, which did not give rise to trouble, did not contain lead and did not give off sulphuretted or seleniurett-
ed hydrogen except at a very high temperature, far higher than any found in industrial operations.

Eye troubles and disorders of the conjunctiva were observed by Chardin in 1926 among women employed in the work of adjusting variable air condensers for wireless in a factory for cutting metal at Besançon.

Excessive work imposed on the various eye muscles which participate in accommodation for distance and light, e.g. the ciliary body and the sphincter of the iris, has caused among adjusters preorbital headache, redness of the eyes with a slight smarting, pain, and even, in one case, conjunctivitis which only yielded to special treatment. Subjects with errors of refraction were particularly liable to these affections.

As regards the action of other products, such as copper, lead, mercury, solvents, acids, tar and pitch, see the corresponding articles. McGowan has emphasised the frequency of tuberculosis among workmen in these industries, the disease being caused by work in hot and humid surroundings, and of infections following wounds by copper wire.

More important are the injuries caused by electric currents, especially during the supervision and control of various apparatus: for example, the impact of the skin, and shocks to the fingers. Goldberg, who in 1925 drew attention to occupational traumatism of the skin in the electrotechnical industry, sees in this traumatism a factor which favours the action of the current on the body.

According to Drinker and Thomson, the effect of the magnetic field as a source of danger to the body is not proved.

Some experts have dwelt on the importance of psychological examination of electrical fitters (Ruffer, etc.). Mechanical and automatic work adopted by modern technique reduces or removes most of the risks to which the toxic substances used may give rise. But it is necessary to supervise closely the installation and working of exhaust apparatus as well as the application of prophylactic measures, in order to eliminate as far as possible the two most frequent risks: lead poisoning and mercurialism.

As regards prophylaxis of electric shock, see the article "Electricity—Industrial Hazards Caused by".

Legislation

In the Netherlands, cases of mercurialism reported in the industry of electrical apparatus as well as in the generating stations are subject to compulsory notification.

Cases of lead poisoning and mercurialism reported in this industry, as well as illness caused by the other products, are compensated when included in the list of diseases and occupations legally imposed.

Legislation regarding hygiene and the work of women and children is, for some sections of the industry, that laid down for work which brings workers in contact with lead, mercury or chromium compounds, or which exposes them to the inhalation of dust or toxic fumes, as in metal scouring. See the corresponding articles.

In France the Order of 10 March 1927 relates to protection and hygienic conditions in constructional and maintenance establishments for the distribution of electric energy.

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Electricity

(Industrial Hazards Caused By)

French: Électricité (Maladies professionnelles et accidents causés par l').

German: Berufskrankheiten und Unfälle durch Elektrizität. — Italian: Malattie professionali e infortuni da elettricità. — Spanish: Enfermedades profesionales y accidentes causados por la electricidad.

Not only does atmospheric electricity give out electrical energy constantly, but this happens also with electricity applied technically, an example of which is provided by the waves produced by currents of high tension. We are all under the influence of this electrical energy, but those who have to work in an electrical field are surrounded by a particularly dense flux.

The following experiment shows that the body has a considerable electrical capacity and can act as a condensing medium: when a man replaces an aerial antenna in a wireless receiving station, it works, although much more feebly. Waves of electricity, therefore, have their influence on the human body. Similarly, when the
ACTION OF ELECTRIC CURRENTS

Definite facts are available as to the crude way in which electricity acts, causing, as it can, the gravest consequences to the system and even death. These facts enable us to understand to some extent electro-pathology, to give the right treatment and especially to take the measures necessary for the prevention of accidents.

Injury caused by technical electricity occurs in well-defined manner; injury due to lightning, however, is a very complex matter — it is not merely a question of electrical trauma, but also of a mechanical trauma. Often the part played by shock is more dangerous than that of the electricity itself. Electrical shock must not be confused with the phenomena due to concussion in the air, or to things falling or thrown at a distance, etc., which may cause injury erroneously attributed to lightning. A differential diagnosis between the false and true lesions is sometimes difficult.

The pure electrical action reveals itself, at the point struck, always in the same characteristic manner, no matter whether the electrical discharge is technical or atmospheric (see figs. 89, 91 and 93; a trained observer can recognise them at once. The general effects, on the contrary, are less pathognomonic than the local. They can show themselves, even when due to electrical traction in any organ. The clinical symptoms, many and various, are due both to the great nervous excitation (the psychical component of traumatism) and the electrical action itself (the dynamic component).

Electricity spreads in the body both superficially and internally. It irritates especially all the nerves, both exciting and charging them electrically to their hurt, and to such an extent that all the organs are finally affected. The combination of forces when it reaches the central nervous system produces what is called “shock”. The more unexpected the injury, the more violent is the shock. If on the contrary the subject is not taken unawares and can brace himself to resist the electrical action he can soften the effect of the shock and even suppress it. A variety of facts confirms this: engineers and medical men have voluntarily experimented on themselves with electrical currents recognised as fatal and have survived them without damage; tourists on whose statements reliance can be placed state that they have been struck by lightning and have not been rendered unconscious, although they have suffered from wounds and have had
their clothing damaged, and this because they expected the flash. These observations show how persons who have to work close to apparatus under tension or who are surprised by thunderstorms may protect themselves.

The above facts have also practical value. They help in solving the question so often discussed: "What tension can be looked upon as dangerous?" or "Which are the most dangerous high or low tensions?"

There is no doubt that increase in electrical tension does not generally increase the danger, and that, all the conditions being equal, the intensity of the current which strikes the victim may not be stronger. No one will deny that an intensity of a milliamperes passing along the body sets up only an agreeable feeling, whereas one of 10 or 100 milliamperes is undeniably unpleasant. It would be a mistake, nevertheless, on these grounds only, to try and estimate the total action of an electrical effect. Tension and the intensity of the current are among the number of factors the combination of which constitute the condition for an electrical accident.

Cases are reported where the victim has received a current not of 1/10 of an ampere (so much discussed), but one exceeding considerably one ampere, and has not been rendered unconscious. On the other hand, cases are reported where the passage of only a few milliamperes, as e.g. in certain medical forms of treatment with sinusoidal faradisation, has plunged the victim into a state of apparent death. Though in a well-managed experiment the heart can be made to stop beating by the passage of a current of 1/10 ampere, it would not do to regard this as the basis for a hygienic law of any value in relation to electricity. Further proof of this is obtained when the same experiment is performed on a monkey, which, of all animals, most nearly resembles man, because the arrest of the heart's action is then only momentary.

1 It is interesting here to recall what Langlois wrote in his report "Electrical Accidents" prepared for the third International Congress on Occupational Diseases (Vienna, 1914), on the subject of how death is brought about.

After the first medic-legal observations made in France, Brouardel laid it down that death was due to arrest of the heart's action; Bourot went a little further in defining the cause by saying that arrest of the heart's action resulted from inhibition through the passage of a current, this necessarily brought about death by asphyxia. Shield and Delépine considered that disturbance in the cerebro-spinal fluid was also necessary. In 1885-1887, d'Arsonval, after a series of experiments, concluded that death might be directly due to the mechanical disruptive discharge on the tissues, or indirectly to reflex action on the nervous centre and principally on those controlling respiration.

The experimental researches of Tatum showed that death from electricity resulted from a direct paralysing effect on the heart. The theories as to how death by electricity is brought about can be summarised in three groups:

1. The theory of nervous inhibition causing either arrest of the respiration (d'Arsonval) or of the heart (Bourrot).

2. Theory of immediate cardiac paralysis (Tatum, Prévost-Batelli). To these two workers is due the credit of drawing a clear distinction between the two ways in which electricity is brought about: fibrillary contraction of the heart muscle from low voltages; death from nervous disintegration with currents of high voltage.

3. Theory of haemorrhagic and coagulative troubles (Donlin, Jellinek).

Schridde advanced a fresh, at the Congress for Industrial Diseases held at Amsterdam in 1925, the point already discussed by him, as to whether death from electricity does not occur more often among individuals of lower vitality. Thus, among 37 cases he had studied, one only was of normal constitution: the other 26 were specially liable to be affected by the discharge owing to their abnormality: hypertrophy of the thymus (75 grm. instead of 35); of the spleen (3 or 4 times too big); and of the kidneys. The men were tall with highly developed extremities, pale skin and devoid of much hair, short neck, so much as to give the impression that their heads were sunk in their shoulders. According to Schridde, their death from electricity ought to be ascribed to so-called sudden death from the thymo-lymphatic state. It should be worth while, therefore, for industrial undertakings, insurance offices and medical experts to bear in mind these facts observed by Schridde, and to try and find out whether it is a case that special sensibility is shown to electrical currents by persons of poor constitution.

Further if too much stress is laid on this factor it may obscure the issue in explaining a fatal result — which has occurred once — from an earthed current of 60 volts. The importance of establishing the fact of the danger of currents of low tension is considerable (Jellinek noted one fatal case in Budapest from only 38 volts), because it has been considered in many countries that voltage of from 30 to 40 completely eliminated all risk. This one-sided opinion as to the risks leads up to another question, "Are not low tensions more dangerous than high?" Any distinction between high and low tension is unsound. It is really unfortunate from the point of view of hygiene, because it has not only given rise to sterile controversy in medical literature, but has had an adverse effect on the methods to be adopted for rescue.

Formerly, as the result of certain observations, high tensions (i.e. anything over 500 volts) were regarded as more dangerous than low, but for some years past some writers, deceived by...
crude statistics, began to wonder whether low tensions were not more dangerous, and even went so far as to assert that their action must be fatal in certain cases and that it was impossible to save the victims.

A glance at the statistics of different countries reveals the origin of this erroneous view: fatal cases are most numerous in the Netherlands from low tension and in Switzerland from high.

**STATISTICS**

The objection cannot be raised that this fact is due to differences in conditions of work and in objective social conditions. It will suffice to compare the statistics in one country. Thus the statistics of accidents caused by electricity published by the Factory Department of the Netherlands give the following figures as to accidents caused by tensions above 300 volts:

- 1920: 17 accidents (2 fatal)
- 1923: 22 accidents (7 fatal)

While for 1921 there was only 1 in 27 fatal, in 1923 the ratio was 1 in 3. The accuracy of these figures cannot be questioned, but, as presented, they are not in a form which contains the two factors of causation of the accident or the practical lesson to be derived therefrom.

In the United States the fatality of electrical accidents among miners is given as 4.05 per cent. for 1921.

In Great Britain the report of the electrical inspector for 1913 showed that, in central stations alone, there were 65 accidents (2 fatal) caused by electricity, and 416 (17 fatal) in factories.

Increasing use of electrical energy in metallurgy (electric furnaces) is naturally the cause of Injuries, sometimes fatal, among foundry workers. For the period 1911-1914 fatal cases numbered 70; for that of 1915-1918 they were over 99, 14 of which occurred in central stations.

In 1924 electrical accidents numbered 433 (27 fatal), as against 361 (21 fatal) in 1923.

Of the 433 cases in 1924, 85 (6 fatal) occurred in central stations, 67 (1 fatal); in factories for electrical equipment; rail-ways and tramway services showed 17 (1 fatal); and metal foundries 22 (2 fatal), etc.

In France industrial accidents from electric currents in mines, quarries, factories, etc., can be tabulated thus:

<table>
<thead>
<tr>
<th>Year</th>
<th>Deaths</th>
<th>Permanent incapacity</th>
<th>Partial incapacity</th>
<th>Results not known</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1907</td>
<td>38</td>
<td>15</td>
<td>548</td>
<td>10</td>
<td>571</td>
</tr>
<tr>
<td>1908</td>
<td>36</td>
<td>4</td>
<td>774</td>
<td>99</td>
<td>773</td>
</tr>
<tr>
<td>1909</td>
<td>33</td>
<td>14</td>
<td>744</td>
<td>17</td>
<td>778</td>
</tr>
<tr>
<td>1910</td>
<td>41</td>
<td>5</td>
<td>883</td>
<td>18</td>
<td>947</td>
</tr>
<tr>
<td>1911</td>
<td>56</td>
<td>13</td>
<td>962</td>
<td>26</td>
<td>1057</td>
</tr>
</tbody>
</table>

The mortality statistics for Italy during the period 1908-1917 showed 649 cases of electrocution, of which 436 were of industrial causation, out of a total of 56,088 deaths from all causes of violence, of which again 26,438 were industrial; that is, 67.2 per cent. of the cases of electrocution occurred industrially.

Nearly all electrocutions are industrial, and it is easy to understand how their number increases from year to year. Among all causes of violent death electrocution has the relative position of 1.2 per cent.; in all occupations it is 0.23 per cent., but among electricians and mechanics this rises to 5.1 per 1,000 deaths from all causes; among unskilled workers the figure is 1.9, mechanics and chauffeurs 1.7, train drivers, etc. 1.4, engineers 1. etc. The category of chauffeurs and railway mechanics had five deaths, of which four resulted from their immediate work, whereas railwaymen and tramway drivers and conductors had 11, of which 7 were of occupational origin.

Deaths from lightning number 1,734, of which 463 affected women. Of these 463 affected women during this same period (1908-1917). They occurred chiefly to agricultural labourers, shepherds, woodmen, etc. Of 1,063 cases, 562 were struck while at work, and while the proportion for all occupations was 0.53, for shepherds, herdsmen and woodmen it was 3.7 per 1,000 deaths from all causes, among agricultural labourers it was 0.8, and among engineers 0.7, etc. (See also the article *Electricians* for other statistics.)

In Switzerland the report of the inspectors of electrical installations shows the figures thus:

<table>
<thead>
<tr>
<th>Year</th>
<th>Personnel at the central stations</th>
<th>Personnel temporarily engaged for mounting machinery</th>
<th>Persons not used to the work</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1919</td>
<td>14 (8 deaths)</td>
<td>20 (9 deaths)</td>
<td>19 (12 deaths)</td>
<td>53 (29 deaths)</td>
</tr>
<tr>
<td>1920</td>
<td>24 (10 ..)</td>
<td>28 (13 ..)</td>
<td>28 (10 ..)</td>
<td>90 (42 ..)</td>
</tr>
<tr>
<td>1921</td>
<td>30 (8 ..)</td>
<td>30 (3 ..)</td>
<td>27 (14 ..)</td>
<td>66 (32 ..)</td>
</tr>
<tr>
<td>1922</td>
<td>29 (8 ..)</td>
<td>18 (8 ..)</td>
<td>21 (12 ..)</td>
<td>60 (30 ..)</td>
</tr>
<tr>
<td>1923</td>
<td>13 (3 ..)</td>
<td>22 (6 ..)</td>
<td>30 (14 ..)</td>
<td>65 (33 ..)</td>
</tr>
<tr>
<td>Average 1914-1923</td>
<td>16 (7 ..)</td>
<td>20 (9 ..)</td>
<td>18 (10 ..)</td>
<td>54 (28 ..)</td>
</tr>
</tbody>
</table>
According to occupation the 65 deaths in 1923 are distributed as follows:

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Number</th>
<th>Fatal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineers and technicians</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mechanics and foremen</td>
<td>6 (3)</td>
<td>2</td>
</tr>
<tr>
<td>Machinery mounters</td>
<td>22 (6)</td>
<td>2</td>
</tr>
<tr>
<td>Workmen of various descriptions in the works</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Other workmen</td>
<td>14 (6)</td>
<td>5</td>
</tr>
<tr>
<td>Firemen and soldiers</td>
<td>6 (4)</td>
<td>1</td>
</tr>
<tr>
<td>Servants</td>
<td>3 (1)</td>
<td>0</td>
</tr>
<tr>
<td>Non-professional class</td>
<td>8 (6)</td>
<td>5</td>
</tr>
</tbody>
</table>

Statistics on accidents will continue to be valueless, so far as electrical accidents are concerned, until they are drawn up on quite a different method. It will be necessary to distinguish between verified accidents and unverified; to ascertain whether the current was the actual cause or the consequence of modification in the conditions affecting either the individual (the worker) or the work; and, finally, an autopsy should be obtained whenever possible.

**Pathology**

Electrical accidents ought not to be looked at merely as a technical question or a natural phenomenon: they constitute a social problem, and only meticulous investigation of every case will reveal their cause.

This can be demonstrated by the following facts: in a tin foundry an electric crane fitter came into contact with the lighting standard. He could not free himself and shouted for the current to be cut off. A woman worker cut the current off, and the mechanic, once set free, fell into a vat full of a hot solution of sulphate of soda. The autopsy showed that the current had not killed him, but that death was due to the consequences of immersion and burns.

A builder came into contact with the armature of an arc lamp, which although not in circuit, chanced to be alive. Attempts at revivification appeared at first to be successful, but suddenly he died. The autopsy showed that the man had been suffocated by vomiting, the would-be rescuers having practised artificial respiration too vigorously.

A workman employed where there was a quantity of soot touched a badly-insulated electric light bulb. The current was cut off to free him. The victim fell and disappeared in a mass of soot more than a metre deep, and was pulled out immediately. There was no sign of life and it took twenty minutes to bring him round. The man seemed so well that the doctor confined his instructions to ordering him a warm bath and went away. Soon he was seized with illness, and shortly after died from asphyxiation. The autopsy showed the bronchi filled right into their most minute ramifications with a plastic mass of wet soot which completely stopped respiration. In this case, as in the preceding ones, switching off the current was more fatal than the electric shock.

Numerous similar cases could be cited in which death was not due to the electrical discharges, but to the efforts made at resuscitation.

Often, however, on the contrary, in consequence of failure to begin immediately artificial respiration in accordance with the recognised method, the last flicker of life disappears and the apparent death becomes a real death.

Fig. 59 shows a section of the skin and muscles of the arm above the elbow of a workman who had died as the result of touching the metallic cage of a badly-insulated lamp. Signs of the heart beating and maintenance of the circulation of the blood can certainly be seen to have been present in the man at least ten or fifteen minutes after the accident. Small haemorrhages are to be seen which could only have been produced during life; they had been provoked by the efforts of the
rescuers, who, in practising artificial respiration energetically, damaged the blood vessels so that the blood which was still in circulation had escaped. In spite of favourable conditions, the patient did not recover because the efforts at resuscitation were given up too soon as, indeed, occurs in most cases, unless the appearance of cadaveric signs are awaited.

Fig. 90.

To give a correct idea of what actually can be done in the way of resuscitation after electric shock, positive examples must be cited. In several cases personally known to medical experts, rescuers by commencing artificial respiration in time and continuing it for hours have been successful. The following are two examples:

A lad of 10 years of age with bare feet was in a stable; he seized hold of a badly-insulated lamp and collapsed immediately without giving any sign of life. His parents tried to bring him back to life, but gave up in a quarter of an hour and laid the corpse, as they thought it to be, down. Just then a veterinary surgeon arrived who proceeded at once to carry out artificial respiration, which was successful in an hour's time.

In the case of an engineer who had received a charge of 35,000 volts through the face, return to life was not effected until after three hours' artificial respiration.

This method can be applied both for high and low tension currents, and if done properly and in time the chances of saving life are the same in the case of alternating and continuous current.

Rescue after electric shock is apt to be impeded by two cardinal faults relative to: (1) the manner in which the current is cut off; and (2) the way in which resuscitation is carried out.

Cutting off the circuit is often done in a hesitating way so as to increase the suffering of the victim, as has already been shown, and exposes the rescuers themselves to grave peril. Then the precious few minutes that immediately follow the accident are lost and methods of resuscitation are adopted so contrary to the principles of physiology that they are worse than useless. Finally, after having found that no results have been shown after half an hour or a little more, effort is discontinued and the patient is left for dead.

Further, when the autopsy shows acute oedema of the brain, infiltration or pulmonary oedema, or the other signs to which reference has been made above, it indicates clearly that life has slowly ebbed away. Can experiences such as these not be utilised as a guide to future practice? Improved methods of resuscitation will only come when written rules are no longer followed as at present, when theory is discarded and replaced by the results of experi-

Fig. 91.
But this reform must be accompanied by the abandonment of the view held by numerous medical men as to particular kinds of currents being always fatal. There is no fatal dose of electricity, as is so commonly believed. When the current has acted for only a brief space of time, as in the majority of accidents, it is essentially shock that is the important factor; the principal vital functions are arrested and a fatal issue seems inevitable. There is arrest or suspension of the vital functions such as may occur from other exciting factors acting on the body, not perhaps in quite so intense a way, nor causing lesions of the internal organs: fright, detonation from an explosion, and an unexpected cold douche. These influences indeed, with no electrical action, may bring about catastrophic results. Similarly to these, the electric current, the main part of the effect often exhausting itself on the surface of the skin, affects also, through the nerves or blood vessels, one or other of the central organs and sets up sudden changes. They disappear often as quickly as they come — either spontaneously or following on treatment. That is what is found in daily practice. Experience shows more and more that return to health takes place without sequelae in cases of respiratory arrest, motor paralysis, cardiac affections (even where these are accompanied by respiratory signs), alarming symptoms in the pulse, thoracic pain, air hunger, and other like signs. Though in these cases heart trouble lasting a long time would suggest fibrillation of the heart cavities or simply its arrest, it is impossible to say which is present, as there are no means of telling. Experiments in this connection on the hearts of dogs showing occurrence of fibrillation of the cavities of the heart by passage through it of one-tenth of an ampere have no value in relation to electrical accidents. The experiments are performed subject to such special influences as narcosis, thoracotomy, and artificial respiration, which have no relation to the imponderable factors attending an accident. Finally, it must be remembered that fibrillation in the case of dogs under experiment may recede and the normal rhythm of the heart be resumed, and that a well-conducted experiment and a sudden accident cannot properly be compared. If the dynamics of the electrical traumatism are studied, if an autopsy is carried out, if the internal organs are examined microscopically, and if, on the other hand, the rapid and complete disappearance of the symptoms in the case of those who
recover, are borne in mind, the only conclusion to be arrived at (leaving aside the rarely occurring anatomical lesions) is that all the effects can recede and that almost all the victims can be saved. "Death" from electricity is only an apparent death. It is not without interest to remember that images of mediaeval saints represent cases of spontaneous recovery of people struck by lightning.

Analogy in the pathology of lesions from lightning and from electrical currents is shown not only in extreme, that is, fatal forms, but also in the causation, course and disappearance of the clinical symptoms in those who recover. This analogy is sometimes identical not only as regards superficial injuries, but also those affecting internal organs. The external lesions are so characteristic that they can be regarded as pathognomonic. First, there are the signs left by the current: well defined in form (circles, straight lines, tubular forms, etc.) (fig. 90); the epidermis which remains is often greyish and fairly hard; there is no surrounding redness, and the hairs near by are usually intact. Nothing suggests a burn; pain is absent.

The lesion may be so severe as to attack the bones. The healing process similarly is such as to confirm the error of calling the traces left by the current a burn. The process is really difficult to define because often the tissues affected appear, in the first few weeks, to have been hardly damaged at all. Fig. 91 shows serious mutilation of the right hand of a boy who had touched a high-tension wire; the fingers have all been lost, although at first they appeared only slightly affected (compare fig. 90). In similar circumstances, among young persons spontaneous amputation of the forearm, and even of the upper extremities in their entirety, have been described. It is surprising to watch to what an extent these severe conditions remain localised. Even when extensive, invoking the mummification by aseptic necrosis of the extremities, the general condition of the patient is not seriously affected; fever is not high, nor are there other general symptoms.

Prognosis in the case of lesions caused by electricity is generally very favourable. When the severe general symptoms have passed away, such as loss of consciousness, paralysis, cramps, heart affections, etc., the principal crisis is over and convalescence proceeds rapidly. The cure is definite and working capacity entirely restored.

A very important principle must be borne in mind; treatment should be essentially conservative; active intervention should be avoided owing to the great tendency there is for the lesions to get better of themselves. Only when there are signs of cerebral haemorrhage or oedema or pressure of the spinal fluid should the surgeon be in readiness to arrest haemorrhage and practice lumbar puncture.

This tendency to a cure shows itself both for external as well as for internal troubles. Though the symptoms most frequently affect the vascular and nervous systems, which generally receive the largest part of the electrical energy, they produce also effects on the other internal organs such as the liver (jaundice), the kidneys (albuminuria, haematuria, haemoglobinuria), the intestines, etc.

Among the specially pathognomonic symptoms which can be successfully treated on conservative lines and be completely cured are not only metallisations of the skin produced by short circuits and metallic pulverisation, but also the modifications in the skin caused by lightning. The last named looks like metallisation, but it takes on a spiral form.

In fig. 92 staining can be made out in the form of crescents covering the distal half of the nails. This is due to superficial impregnation of the horny layer by vaporised metal, which took place some six weeks before; the nails were entirely blackened at the time of the accident, but the portion formed since is quite normal.

In one case staining in spiral form and dryness of the skin appeared after a lightning stroke, disappearing completely in one or two weeks, the skin having peeled off.

**Treatment**

At the present time, therefore, precise knowledge as to how to treat the victims of electrical shock is available, thanks to the clinical observations made for years past and numerous experimental researches. Treatment can thus give the happiest results and present-day medical experience even permits of laying down rules for the prevention of electrical accidents by methodical analysis of such cases as have occurred, and of formulating adequate prophylactic recommendations.

Whilst formerly wounds of the extremities were treated by amputation, and, as has been shown, the lesions of the internal organs were treated vigorously, and the victims were thought to
be dead after a short lapse of time, it is now known how readily the lesions heal spontaneously, and that death from electricity is only an apparent death in the majority of cases. It is certain, therefore, that an organised rescue system will be productive of the best results.

Not so long ago it was held that a woman struck by lightning when far gone in pregnancy was practically dead, and that the child should be saved by caesarean section. It is now believed, on the contrary, that no caesarean section should be effected, but an effort made to save the mother by artificial respiration. This imperatative indication is confirmed by animal experiment; the foetus survived fairly long during the time of apparent death. Jellinek has succeeded after killing a bitch by electricity, in removing the litter more than a quarter of an hour afterwards and was able to keep them alive for several days. Since the foetus would not appear to suffer from injury whether the electricity is from an atmospheric or technical source immediate attempts should be made to save both mother and child by artificial respiration.

Prevention

As with therapeutic measures, so also with preventive; they must be based on experience and study of particular cases.

Rules laid down by electrotechnical associations and legal or administrative orders may contribute in large measure to the safety of workers, but it should not be forgotten that the majority of the accidents are due to ignorance on the part of the public of the risks run and the rules to be observed in handling domestic articles. Many are the cases where indifference or culpable levity breaks all rules and exposes their perpetrators to danger even when they have been warned.

How many persons are there competent to warn the public, for example, how serious a risk lies in the ordinary incandescent electric light bulb? In Vienna alone in 1924 seven persons lost their lives as a result of contact with badly-insulated lamps. Is the housewife always aware that the electric iron or the kettle or apparatus for drying the hair may cause severe burns, and even death? And do householders attach as much importance to properly installed systems as they do to the rapidity with which these are effected even when the price paid is risk of fire?

Is it not usual to find people who are not electricians regarding a tension of about 100 volts as a bagatelle and connecting themselves up in circuits to test installations without using as a precaution a voltmeter or lamp, even when they know very well that to do so may cost them their lives?

All these dangers are still further increased by the fact that earth connections become more and more common in workrooms and in the home by reason of the multiplication of electrical wireless installations. Wireless in fact may cause an accident if a man has on his head earphones and holds an electric lamp the brass handle of which is charged as a result of defective insulation.

All these facts warrant a systematic propaganda against electrical accidents, and this should not be directed only to persons employed in factories, workshops, mines or the transport industry, but should also extend to the public, and particularly to boys and girls in schools. Such popular education should be undertaken jointly by medical men, teachers and engineers, with the aid of cinematographic films and demonstrations. Nor should practical exercise in the methods of rescue be omitted. As a further means in the rational prevention of accidents selection should be practised among the young persons who express a wish to take up technical electrical work or seek employment in electrical supply services for their livelihood. It is a certain fact, for instance, that among the fatal cases there are found too many where there has been present the handicap of bodily or functional susceptibility (lymphatic diathesis, premature closing of the cranial sutures, small heart and other anomalies), which exposes the victims of accidents to the risk of sudden death from natural causes. The lives of such persons are seriously menaced by an electrical discharge of minimal amount. They are less resistant and ought to be kept away from the risk of harming themselves. Similarly, those who show particular susceptibility, whether psychical or corporal (increased conductivity of the skin from sweating hands or feet, for example), offer a lowered resistance and ought to be excluded from all work in connection with electrical apparatus. On the other hand, the extraordinary variability of individuals in regard to tolerance of electrical discharge is a factor which plays an important part in the production of electrical accidents constituting a factor indeed not less important than that of the tension. Hence
candidates for work in the electrical trade should undergo a practical selection test by a trained medical man on this point.

Since life and practical experience are constantly imposing new tasks, an office should be created to assemble and study the literature and documents relating to electrical accidents. Such an office might well become a branch of other public welfare services. A register would be kept there of accidents investigated by medical men and engineers, and it would be possible, by adopting new statistical criteria, to issue promptly practical rules for prevention and safety. This office would come to be regarded as the official source for all electrotechnical inventions and improvements in regard to safety which would soon acquire wide recognition and application. Such an office, too, would be of immense value by giving in an advisory capacity to administrative bodies, the courts, and insurance offices, and represents in this connection an institution the need of which has long been felt. How useful it would be from a national and economic view can be judged by the light the data collected by it would throw on accidents from lightning in providing accurate statistical data.

Further, in addition to the information such offices would collect for individual countries, their studies would give an impetus to international action (conferences and congresses) for the promulgation of preventive measures adapted to present needs.

There is no department of public welfare where more useful work from an international standpoint, both for individuals and the community in general, can be done than in a campaign against the dangers of electricity and of its pathological effects.

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See the works of JELLINEK, and further the Bibliography of Industrial Hygiene published by the International Labour Office.

The plates used in this article have been kindly lent by the author.

**Prof. S. Jellinek**

(Vienna).

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**Electroplating**


**INDUSTRIAL PROCESSES**

Strictly speaking, electroplating is the art of applying by means of electricity a metallic deposit on objects, but generally the term is used to cover all deposits of a metal on any surface by an electric current ("galvanic deposit").

These processes are based on the phenomenon of electrolysis. When an electric current is made to pass into a solution of a metallic salt, the metal is deposited on the cathode (negative pole) while the acid part of the salt remains at the anode (positive pole).

If the anode is made of a metal which can be attacked by the acid in question it dissolves little by little. In using an anode of the same metal as that of the salt impoverishment of the bath is avoided and the metal is carried from the anode to the cathode. It is sufficient, therefore, in order to coat an article to place it at the cathodal end after having closed the connection.

**Electroplating**, properly speaking, embraces a great number of operations, the principal of which are moulding, metallisation by means of graphite, and deposition of the metal electrolytically.

Methods vary very much. Consideration will only be given to those which have interest from a health point of view.

Before moulding the articles are subjected to a careful degreasing with benzine. An impression is then taken in a fusible alloy (often containing lead) or soft rubber or wax. Other methods involve use of plaster mixed thin, mixtures of gelatine and molasses, etc.

Metallisation (see that article) has for its object to render the article a conductor. It is dipped in a bath of stearine or fatty matter and then rubbed with a brush coated with graphite.
The term "metallisation" is thus used inappropriately. Mention must be made of risks incurred with certain special methods of metallisation: treatment with an alcoholic solution of silver nitrate and reduction with hydrogen sulphide or phosphorus dissolved in carbon bisulphide, exposure of the object coated with nitrate of silver to the vapour of mercury, etc.

Casts are often made in copper, which can then be gilded, silvered or nickel-coated.

Electroplating is employed in the reproduction of statues, medals, etc. Actually its principal use is in the reproduction of plates for typographical prints, postage stamps, bank notes, steel and wood engravings. Printing blocks, spoken of as "galvanos", are thus obtained. To give them thickness and sufficient rigidity they are coated with a metal or filled inside with printing alloy.

The electrolytic deposit which adheres to the articles gives them a richer or pleasanter appearance and preserves them against oxidation. The processes most frequently practised are copper coating, nickel coating, silvering and gilding. The electroplating is carried out in glass, porcelain, fireclay or wooden vessels or baths, lined inside with indiarubber. The current is furnished by accumulators or dynamos, rarely by cells.

Sources of Danger

The methods and kinds of baths used vary very much for the same metal, according to the size of the articles to be dealt with and the thickness of the coating which it is desired to apply. Danger comes especially from the fact that the majority of the baths contain cyanides. Hydrocyanic acid is liberated at the anode and some of it is given off. The factors influencing its evolution are: the composition and temperature of the bath, the tension and density of the current.

(a) In the course of copper coating several processes have interest on the score of health: degreasing by means of boiling solutions of soda or potash; pickling or removal of the oxides, with 10 per cent. sulphuric acid; scouring with dilute nitric acid; brushing with a paste composed of slaked lime in order to remove the last traces of fatty matters.

The salts of copper most frequently used for electrolysis are the sulphate and carbonate; the oxide is also used. The bath for small objects contains potassium cyanide.

Copper coating is in common use as it is necessary to treat iron, cast iron and zinc with it before proceeding to nickel, silver or gild them.

(b) The preliminary processes of nickeling are similar to those for copper coating. The deposition takes place in a bath of sulphate of nickel with the anode of pure nickel. The bath does not generally contain cyanide, but the articles before electrolysis are often dipped in cyanide of potassium. After the process of nickeling is finished the object is washed in water, dried, and polished on a calico or felt mop covered with Spanish white (chalk sometimes containing white lead) or English red (sesqui-oxide of iron).

A great variety of articles are nickel coated to protect them against oxidation. Copper rollers used for printing on paper or cloth are similarly nickelled in order to make them last longer.

(c) Silvering is generally done on copper. The article is freed from grease, scoured, pickled, as has been described above, then it is covered with an amalgam in order to make the deposit adhere better; to do this it is dipped into a bath containing sulphuric acid and bioxide of mercury and successively treated with solutions of cyanide of potassium and sublimate. These solutions are cold; there is generally no escape of gas.

In the process of electrolysis the cathodes are of fine silver, the electrolyte being the double cyanide of potassium and silver obtained by dissolving nitrate of silver and cyanide of potassium in water. The silvering is most frequently carried out in a cold bath; the reaction is slow and the hydrocyanic acid which boils at 26.5° C. does not spread far into the air. The danger is very great when the silvering process has to be done rapidly, the baths being hot and the tension five or six times stronger.

The processes end with the finishing, polishing and scratch brushing with Spanish white or English red, burnishing, etc.

All the objects must previously be freed from all trace of silver in a bath composed of sulphuric and nitric acid.

(d) Articles to undergo gilding, after having been freed from grease and after pickling and washing, are treated in baths of varying composition, but always containing cyanide of potassium and gold chloride. There is no soluble anode; the current is conveyed by a platinum wire which remains unattached. The bath is then exhausted, and fresh salts have to be added from time to time.
Gilding is more dangerous than silvering because, though the process goes on at a temperature of 60–70° C., the quantity of hydrocyanic acid given off is greater.

Distinction has to be drawn between what has been described and "electrical plating", where a very superficial coating of gold is applied to plated layers in order to remove the visible solder marks and obtain a uniform colour. This last operation is more injurious for the workman because it involves intermittent and intensive employment near the vats.

The "coloured golds" (white, red, or green gold) are obtained by adding copper, silver, etc., to the baths.

In order to prepare the gilding and silvering baths, the salts are obtained from firms preparing chemical products or they are made in situ by dissolving the silver in nitric acid and the gold in aqua regia. These processes lead to the evolution of nitrous fumes and ought to be carried on in closed air-tight receptacles or in the open air as is done in small premises.

Some works make use of the following process for dissolving the gold: electrolysis is carried out with a solution of cyanide of potassium, pure gold forming the anode and zinc the cathode. The two electrodes are separated by a diaphragm. The gold is gradually attacked by hydrocyanic acid and passes into solution. This process develops more hydrocyanic acid than gilding and ought only to be done under exhaust hoods connected up to a fan.

Galvanic silvering and gilding is practised in jewellery and passementerie (threads, braid, buttons, etc.).

(e) Platinum-coated baths contain cyanide or sulphocyanide of potassium and platinum chloride.

(f) In chromium plating generally, use is made of a solution of chromic acid (200–500 mg. per litre) and traces of other ions, particularly the sulphate, which is introduced into the bath as sulphate of chromium or in the form of sulphuric acid. Sometimes the bath contains variable quantities of trivalent chrome or trivalent iron (derived from the iron in the vats) or from the anodes if they are kept in solution or in a colloidal state.

The anodes of lead commonly used may give off small quantities of lead chromate or of lead peroxide which become deposited on the surface of the anodes or may pass into solution. Similarly the oxygen, given off at the anode, and the hydrogen coming off in quantity at the cathode, carry into the air tiny droplets from the liquid of the bath in the form of a fine mist, which contains the obnoxious element chromic acid.

Electrolytic chromium plating requires currents of high density and heating of the electrolyte (to 80–90° C.). The management of this bath is very delicate. In the course of the process the very corrosive solution gives off a highly dangerous vapour which requires to be caught and removed by carefully designed exhaust ventilation. Chromium plating of brass especially requires as a first step much polishing with emery, greasy cloths, greasy sheep skin and tampico brushing.

PATHOLOGY

The dangers for the safety of the workmen engaged in electroplating consist primarily in the risk of intoxication by hydrocyanic acid given off from the baths. This is especially so in the case of the silvering and gilding baths, and the danger increases as the intensity of the current and the temperature gets higher.

Intoxication by hydrocyanic acid presents symptoms which differ according as whether the intoxication is acute or chronic (see articles "Hydrocyanic Acid" and "Cyanogen"). The cases of chronic poisoning which are very frequent have been known for a long time (Martin, 1888; Merzbach, 1899; Kober, 1902, etc.).

Experiments have been undertaken to ascertain the individual reaction to prussic acid poisoning. Animals are able to remain for several hours without harm in an atmosphere containing sufficient hydrocyanic acid to be detected by the usual Guignard test (formation of isopurpuric acid) and by the Petrusi-Gastaldi (benzidine and copper sulphate). Tests taken at the surface of small silvering and gilding baths are always slightly positive, while at the level of the face negative.

With larger baths the quantity of hydrocyanic acid given off is naturally greater, it being granted that there is increased concentration, higher temperature, wider surface for evaporation and strength in the tension (Koelsch).

An enquiry made to try and show the existence of cases of illness due to the inhalation of hydrocyanic acid in small and large electroplating workshops yielded negative results, although in the atmosphere of the majority the sense of smell readily detected the presence of hydrocyanic acid. The natural deduction is that workpeople can tolerate without harm...
This ulceration is due to the action of caustic substances and the coloration and pigmentation to impregnation with the chemical substances.

In Great Britain several cases of vesicular dermatitis were observed in women employed in galvanic gilding. It was noticed that contact with the electric wire when a weak current was passing through set up irritation of the skin limited to the internal side of the fingers in contact with the wire. In Prussia, a workman engaged in galvanic deposition of arsenic was affected by deep purulent sores situated on the hands. The baths contained equal parts of cyanide of potassium and arsenic and a small proportion of acid phosphate of soda. In Saxony, in a large zinc electroplating establishment, during the first two months of its operation, 10 cases of purulent inflammation of the hands occurred among the workers employed in brushing the galvanised utensils. They were due to small lesions on the hands which were brought into contact with the electrolyte composed of zinc sulphate of aluminium. In Austria, some workmen engaged in silvering certain metal articles developed open pustules situated on the hands. They were met with most frequently among those cleaning the articles as they were removed from the bath, in water, soap and water and pumice stone or with the brush of brass wire. Localised ulcerations may penetrate to the bone (Chanel). (See also article "Nickel").

Localised acute dermatitis can be seen also on different parts of the body: the face, ears, neck, nose and often also on covered parts of the body. The Bureau of the United States in 1928 undertook an investigation into the injurious action of chromium plating. In general there is used a solution of chromic acid, the spray from which, thrown on the workmen, exerts an action so injurious that employers have been obliged to take necessary measures of prevention.

The enquiry was conducted in seven workshops employing 27 workmen; at the same time more than 100 persons working on the same premises were to some extent exposed to the action of the injurious vapours. The enquiry was simply concerned with ascertaining the extent of the danger; but the results obtained are of great interest.

In the course of their enquiry the investigators, Bloomfield and Blum, examined 19 workmen employed on the electroplating baths; 4 worked in the same room, but at a distance of 3.50 metres and more from the vats; 5 men...
engaged in other work served as a control.

The 19 persons examined at chromium plating had a duration of employment of from a week to three years; the hours varied from two to seven daily; the approximate quantity of chromic acid inhaled by each workman was 1.2 to 56 mg. per 10 cubic metres of air (in the case of 5 it was not determined).

Perforation of the septum of the nose was found in 3 of them (16 per cent.), in 2 of whom it was marked; ulceration of the septum in 4 (21 per cent.); irritation of the mucous membrane was marked in 9 (47 per cent.) and slight in 8 (42 per cent.); the nose bled easily in 11 (58 per cent.), even on simply touching it; chronic chrome holes, situated generally on the hands, were noted in 5 cases (26 per cent.).

Only two workmen showed no lesions from chrome. It is important to note that of 4 men working in the same room as the electroplaters, 3 showed lesions of the nasal mucous membrane.

The controls were perfectly free from lesions.

Foerster (1926) had already drawn attention to the risk from lead and the chromates among persons employed in chromium plating as a result of insufficient precautions. He was concerned with the lesions to the hands from the chromates, to their action on the mucous membrane, as well as to cases of lead poisoning from lead chromates. Foerster had recommended replacing the parts of the apparatus made of lead by aluminium.

**Hygiene**

The workrooms should have ample ventilation and the floor should be of impermeable materials sloping to a central drain and collecting, by means of gutters, the liquids accidentally spilled. The effluent should not be allowed to enter the sewer until after adequate neutralisation.

The processes in which injurious emanations arise (pickling for example) should be carried out under a hood the front and sides of which should be capable of being closed and connected up to the chimney stack or a fan. When mercury is used in the gilding process a movable hood should be placed over the amalgamating and volatilising hearths and be connected up to a very powerful exhaust. Measures should be taken to ensure condensation of the toxic vapours.

When cells are used they should be placed under a closed-in hood; the same precaution should be taken in the case of the dipping baths. If the town's current or that from a dynamo is used the necessary safety measures should be taken to protect the workers (isolation of every installation, earthing of vats, etc.).

In general the law requires that all poisonous substances used in the works be kept under lock and key, and that the workpeople should be warned as to the dangers of the different chemical substances employed in the industry.

Bloomfield and Blum (1928) have shown that natural ventilation is rarely efficacious; that vertical artificial ventilation obtained by hoods is also ineffective, because the current raises a mist and throws it on to the face of the workman engaged at the vat. Recourse, therefore, must be had to local exhaust ventilation, but apparatus should be arranged along both sides of the bath or the centre. Whatever arrangement is made the amount of chromic acid should be kept below 1 mg. per 10 cubic metres of air. Care should be taken to see that the level of the bath remains at about 24 cm. from the edge of the bath and the velocity of the exhaust draught should be at least 600 metres per minute. Every care should be taken to keep up a good draught. The use of a hood is always desirable as it prevents any contrary action of air currents in the room.

It would be better to determine how the aspirating system is functioning by means of the kata-thermometer instead of by a simple anemometer.

The contact of the air in chromic acid should also be determined periodically either by means of iodine and thiosulphate, or, if it is present only in traces, by means of a colorimetric process (with haematoxylin).

The workers should be protected as described in the article "Chromium and Chromates": personal hygiene would enjoin the wearing of gloves, rubber shoes, aprons, etc. If gloves are not worn, ointment should be applied to the skin; a periodic examination of the workers should be arranged, etc.

The affected parts can be treated with a 5 per cent. solution of bisulphite of soda or with oxygenated water; a solution of thiosulphate is also advised. For ulcers of the skin ichthyol ointment is also advised. Prevention of skin maladies demands, therefore, above all rigorous bodily cleanliness. As to the employment of substances to protect the skin it has
to be remembered that their use (vaseline, lanoline, etc.) in some processes is impossible, because the galvanic deposit cannot form on metal covered with grease spots. Where, therefore, such procedure is out of the question recourse must be had to rubber gloves. Another method suggested is the selection of workers excluding such as show particular sensitiveness or are already suffering from skin maladies. After work the hands should be washed with soft soap and smeared with an ointment consisting of zinc oxide or lanoline.

Direct contact with the corrosive liquids should be avoided, as much as possible by using hooks for the withdrawal of articles from the baths. Further, the workpeople employed in the cleaning operations ought not also to be engaged at the baths and vice versa.

**Legislation**

Pregnant women and young persons under sixteen years are prohibited from rooms where electroplating is carried on in Argentina. In Italy boys under fifteen years of age and women under twenty-one are not allowed to be employed in gilding and silivering, etc.

Few special regulations have been enacted for this industry. Thus Prussia alone lays down the principles which should serve as a basis for health guidance in the jewellery workshops of Hanover (11 November 1903), and an Order dated 12 March 1902 on the preservation and use of potassium cyanide and arsenic compounds in the gilding and silivering of metal articles. Requirements dated 27 August 1906 were laid down in Württemberg on the hygiene of jewellery workshops. In Great Britain a Welfare Order of 1921 (No. 2032) requires the provision of sufficient and suitable overalls for persons working with materials in a wet state or coming into contact with acids or acid solutions, the distribution of finger stalls or rubber gloves or other sufficient protection, aprons, etc., which will withstand acids, etc.

Cases of mercurial poisoning reported among workpeople employed in water gilding are statutorily notifiable in France and the Netherlands. Cases of poisoning by mercury, arsenic, dermatitis due to cyanogen compounds receive compensation in countries where diseases coming under the Workmen’s Compensation Goves are scheduled (see article “Industrial Diseases: Compensation”).

**Bibliography**


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**Emetine**


Emetine is one of the alkaloids contained in the root of various kinds of ipecacuanha.

In the pure state, formula $C_{22}H_{22}N_{4}O_5^-$, it appears as a white powder with a bitter, disagreeable taste; it is not easily soluble in cold water, but is more so in warm water and very readily in alcohol and ether. It is affected by light which changes the colour to yellow; it readily forms soluble salts in water, alcohol and oils. The commercial product is seldom pure and is often known under the name of “brown emetine” or “medicinal emetine”, a kind of extract of ipecacuanha.

The preparation of emetine is carried out by boiling the roots of ipecacuanha, and then extracting by ethereal solutions.

*Damage* may be sustained during its preparation by workers at chemical works, or during its use or that of ipecacuanha by druggists and pharmacists.

The toxic effect of emetine, as of the other alkaloids of ipecacuanha, cephaline and psychotrine, is chiefly from contact, through irritation of the mucous membranes, as has been shown through experiments on animals by Lewin and Kober, or through clinical observations. Emetine, like the other alkaloids, also exercises, as the result of absorption, a strong emetic effect.

Many persons show a very marked idiosyncrasy to emetine or ipecacuanha. Benjamin has recorded rubefacient eruptions and generalised exanthemata. Riechen noted a case of asthma caused solely from smelling ipecacuanha. Kober has reported a condition of malaise in one of his pupils from the same cause.

The available statistics refer to some cases of dermatitis noted by Lewin among pharmacists. Prosser White reports several cases of poisoning from the use of ipecacuanha powder; the English Factory Inspection Department in 1920 became cognisant of several cases of dermatitis which occurred among workmen employed in the manufacture of emetine. Turner, quoted by Morrow, mentions a case of serious exanthema with asthma and bronchitis. Galewsky has described 3 cases of dermatitis during the extraction of emetine; 1 was a chemist and 2 were workmen. Recently (1926) several cases have been reported by Dr. Kruger, of Dresden, in the course of the manufacture of this product.
The pathology is characterised by dermatitis with swelling, redness and exanthem; this last occurs sometimes with pustules, which leave scars on healing. Widal, Abrami and Joltrain have noted a vesicular erythematous eczema of the face which came after an incubation of fourteen days. The lesions occur chiefly on the posterior part of the forearm and the dorsal surface of the hand, and sometimes on the neck, the face, and the nape of the neck. Inflammation of the eyes and nasal mucous membrane have also been noticed. Among the general symptoms which arise in case of overdose, are vomitings, palpitations with cardiac irregularly (J. H. Broers), and anaphylactic asthma and bronchitis, of which one case was observed by Varekamp in 1925 affecting a chemist's assistant. In the case reported by Krüger, headache, excitement, insomnia and fever causing interruption of work were reported.

The various disorders found disappeared on the cessation of work.

Injuries caused by alkaloids are compensable under Swiss legislation.

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Enamels, Enamelling


Enamels are finely powdered substances which vitrify at a high temperature, and are used for coating numerous articles with a protective layer or for the purpose of decoration. Chemically, enamels are metallic silicates made fusible by boron (borax and boric acid) and fluor (fluorspar and cryolithe).

Various oxides are added to enamels according to the coloration desired; cobalt gives blue; cobalt and manganese give violet; copper and chromium give green; and iron gives brown, etc.

As regards this very delicate operation, let it suffice to state here that the colours are not the same with lead enamels as with enamels without lead.

The formulae for enamels are numerous and their composition varies according to the articles to be enamelled, to the furnaces and temperature used, and to the methods of application. Lead enamels, which generally consist of quartz, soda and oxide of lead, are distinct from the leadless enamels.

The following types of enamels are also recognised:

1. Opaque enamels. — These include generally enamels containing lead up to 40 to 50 per cent. and arsenic; after their application they have a uniform shade, both in relief and in hollows. Usually coloured, but especially as white, they often form the bulk of the first coat applied to pottery.

2. Ceramic enamels. — These generally contain 55 to 70 per cent. lead, and sometimes 1 to 5 per cent. arsenic. Used chiefly for covering relief castings, they give, after application to the object covered, an appearance of a baked pottery which has been subsequently enamelled.

3. Sanitary enamels. — This generally contains no lead or arsenic; it is used chiefly for the white enamel on cooking utensils, and sanitary ware.

These enamels eliminate all risk from lead and from arsenic for the workers concerned.

INDUSTRIAL OPERATIONS

The weighing and crushing of the raw materials. — These operations are generally done by hand. The materials, having been rather finely crushed, are collected in a mixer placed under an exhaust ventilator. In the case of lead enamels, the product used, whether red lead, litharge, white lead, or lead sulphate, is weighed separately and introduced during the last stage.

The mixture is then melted in open-hearth furnaces or in crucibles. After melting, the enamel is subjected to crushing, pounding and bolting. As soon as it is cold the enamel breaks up of itself and tends to fall into small pieces. The pulverising of enamel is done by a crusher and then in a shot mill, and a screen.

Putting into barrels and packing in boxes are the final operations of manufacture, which must be done mechanically in closed apparatus.

Enamelling

The industrial art of enamelling has been much developed since the war, so that for practical reasons enamelling works are built by side with enamel factories. Some firms even combine the two kinds of operations.

A. — Most enamelling consists in the application of common enamels to such metal articles as: enamelled cast iron, composing household articles, heating apparatus, stoves and baths; enamelled sheet iron, composing sanitary ware, kitchen utensils, buckets and saucepans; and enamelled plates, used for advertisements and signs.

Enamelling on metals includes cleaning with acidulated water the articles.
to be enamelled, which are then washed, dried, passed through sand, and the preparation of the enamel mixture. Two mixtures are often used; a foundation forming the "body", and a glaze or enamel properly so called, which are generally arranged in heaps on a metal table. The actual application of the enamel is done in the form of either a powder or a liquid.

When enamel is applied as a powder the articles are first brought to a cherry red heat in a furnace. Then they are withdrawn from the furnace and plunged into the "body", shaken, and next immersed forthwith in the enamel, for the process of enamelling or immersion; after which they are put back into the furnace. In the case of large articles, a workman first sprinkles the article on coming out of the furnace with the "body" by means of a hand sieve, then, when that material is well distributed, the same operation is repeated with enamel or glaze. If, during the application of the "body", the article has cooled too much, it is reheated between the two applications.

Shovellers and enamellers are assisted generally by a young boy who, from a distance, opens the furnace and, during the process of enamelling, comes up to the enameller and assists him by holding the articles to be enamelled.

These articles, when sprinkled, are hung on supporting rods, and put back into the muffle furnaces for baking; then they are taken out and put on the ground to cool.

Articles of very large dimensions are sprinkled actually in the furnaces by means of special devices.

Enamel on articles of small size is not melted in a furnace, but by means of an enameller's lamp or by a blow-pipe.

When enamel is applied by the wet process, objects to be enamelled are cleaned by boiling or brought to a red heat. The enamel after the addition of pure water is pounded in a mortar and brought to the consistency of cream, which is then applied either by immersing the object, or by painting it with a brush. After drying, decoration may eventually be put on, either by hand painting or by transfer. The article is then dried fresh in a stove before being again baked.

Enamelling by the wet process may also be done by projecting the enamel by means of a pistol similar to that used for spray painting.

Sometimes the two methods are combined; and, when ceramic enamels are used, the articles are sometimes covered with three coats; a body foundation is applied by the wet process in the form of slip, and then dried; a body-enamel is next applied by the dry process or by sprinkling; and lastly, an enamel coat is applied by sprinkling.

B. — The enamelling of ornamental tiles is also an operation very extensively carried on. The raw materials are mixed in a tub with water to form a thick whitish cream, which is generally applied to the surface to be coated. Less frequently the surface to be coated is dipped in the cream. The enamel is then fixed in the form of a transparent or opaque vitrified layer by baking the tiles again at 1,100° C.

Sources of Dangers

(1) During the Manufacture of Enamels

(a) Dust is given off when red lead or minium is put into the mixing apparatus and when furnaces are charged from above and the draught tends to throw back the poisonous dust on to the workman. Poisoning occurs chiefly among the men who feed the ovens. On the other hand, charging the furnaces from the side does not present any danger, for the furnace draught induces a strong rush of air to the interior.

(b) When the furnaces are drawn too hot, sublimation occurs of whitish, lead-bearing fumes, which afterwards penetrate in the form of dust into the workplaces.

(c) When enamel is crushed, dust is generated, but there is much less dust if the enamel has been thoroughly fritted.

(d) Barrelling and boxing are two very dusty and very dangerous operations, if not done mechanically in closed apparatus.

The degree of toxicity of these dusts is naturally dependent on their content in lead. The presence of other products, such as arsenic, antimony, chromium and chromates, must not be overlooked.

According to Kober and Hayhurst enamel workers are exposed to injury from the following poisonous products: amyl acetate, arsineiurtted hydrogen, benzene, carbon disulphide, carbon monoxide, hydrochloric acid, nitrous fumes, acid fumes, nitric acid and turpentine. Prosser White refers to the use of naphtha derived from coal-tar for the preparation of colours for enamels.
(2) During the Use of Enamels

The dangerous operations are chiefly immersion and sprinkling. Some cases of lead poisoning have been observed even among warehousemen or labourers who have to remove the finished articles. Then again, in spite of all precautions, quite a large quantity of enamel falls on the ground, where it is trampled on all day. Poisonous fumes, chiefly of lead, are given off at the moment of immersion, or of sprinkling powdered enamels on to red-hot cast-iron articles.

According to some authorities absorption of lead by the skin may be particularly facilitated by the fact that the men work partially unclothed and covered with sweat.

Mention must he made of the action of dry heat from exposure to the intense radiation from the furnaces or from the large articles which have to be enamelled.

<table>
<thead>
<tr>
<th>Years</th>
<th>Number of works</th>
<th>Number of cases of poisoning</th>
<th>Number of days of incapacity</th>
<th>Total of sick payments</th>
<th>Number of workmen employed</th>
<th>Weight of enamel at works using lead</th>
<th>Weight of enamel at works not using lead</th>
</tr>
</thead>
<tbody>
<tr>
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<td>4</td>
<td>8</td>
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<td>54</td>
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<tr>
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<td>46</td>
<td>853</td>
<td>10,961.50</td>
<td>134</td>
<td>5,045.983</td>
<td>2,011.173</td>
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</tbody>
</table>

* Only personnel employed in the manufacture of lead enamels have been included.

In the table on page 681 the figures in ordinary type refer to enamel works, and those in italics to enamelling works.

For an equal weight of lead enamel, taken as a unit, the number of cases and days of sickness is forty-two times greater in works where enamels are applied, than in those in which they are made. The importance of lead poisoning in the latter seems to be rather on the decrease, but in the enamelling works, on the contrary, it seems to be growing worse in consequence of increased production of enamelled goods and a lack of fully trained workmen.

Available statistics relate almost exclusively to lead poisoning.

In Belgium, an enquiry carried out in 1926 by the factory medical service into conditions affecting 15 enamellers showed that 73 per cent. of the men showed certain signs of impregnation by lead. Blood examination showed in 11 workmen punctate basophilic red cells, sometimes as numerous as 2 to 3 per field; 7 workmen showed the line on the gums; there was 1 case of lead colic; and 1 case of neuritis with feelings of numbness in the upper limb.

In France, in 1921 there were 53 cases of lead poisoning in metal enamel works; in 1922, 286 cases; in 1923, 278; in 1924, 453 cases; in 1925, 456 cases; in 1926, 635 cases; in 1927, 335 cases.

Some very instructive figures are those relating to lead poisoning in the enamel works of the Ardennes for the years 1921-1922-1923 (Chevalier).

Further, from the fact that risks of lead poisoning are more apparent in enamel works a stricter watch is maintained there over the protection of the workers. The measures of protection are also easier to carry out, for nearly all the operations can be done in closed apparatus.

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1 According to the divisional inspector of Nancy, the diminution of cases of lead poisoning was said to be due to a slowing down in the activity of the enamel works of the Ardennes region and to an improvement of the hygienic conditions, consisting chiefly in increased use of enamels without lead (1927 report).
According to an enquiry made in 1924 by Heim de Balsac, Agasse-Lafont and Feil, in two factories manufacturing ceramic enamels, the hygienic conditions of the two factories were very different. One employing 29 persons, of whom 16 were examined, used an opaque stannic enamel, a double silicate of lead and tin derived from oxide of tin and of minium. The percentage of stigmata and sickness attributable to lead poisoning was small. The enamel was used in solid form or coarsely crushed, or in a very liquid paste. The other factory employed 200 workers of whom 50 women were engaged in making enamelled tiles. The examination dealt with 36 persons. A line on the gums was present in 10 per cent. of the decorators, in 16 per cent. of the enamellers, and in 50 per cent. of the enamel makers. Punctate-basophilia was present in 16 per cent. of the tile workers, in 40 per cent. of the decorators, 67 per cent. of the enamellers and 100 per cent. of the enamel makers. Contrary to what Chevalier found, the investigators reported that the making of enamel, with mixing and handling of different lead compounds, is the most dangerous proceeding. All the workmen showed signs pathognomonic of lead absorption, with at least a slight degree of punctate-basophilia. This proportion decreased for other operations, where enamel or other lead products are used for enamelling ornamental wall tiles, or decorating or enamelling plain tiles.

In Germany from 1912 to 1922, 24 cases of lead poisoning were reported in the State factories for the manufacture of enamels or for enamelling. In 1923-1924 other cases were reported: in three iron foundries of the district of Osnabrück and Aurich medical examination of workmen employed in mixing and applying enamels disclosed 4 cases of lead poisoning which necessitated change of employment for those affected. In addition, one slight case was found in a woman employed in powdering enamel.

Twenty-one cases of lead poisoning, some of which were erroneously diagnosed, were noted in a factory making earthenware stoves in the district of Potsdam. In addition, medical examination, accompanied by blood analysis, of two enamellers in a large stove factory of the Minden district showed one of these men had changes of the blood formula, clearly attributable to the effect of lead.

In this concern, a litre of milk was supplied free to the workmen handling enamels.

During the same period some cases of lead colic were noted in Bavaria in a factory for stoves, and in a factory for ornamental tiles for walls. Examination of the notifications in the Sickness Fund office common to these two establishments brought to light 5 cases (4 men and one woman) in the stove factory and 3 cases (1 man and 2 women) in the tile factory.

In an enamelling works at Württemberg, where a frit with 50 per cent. lead is used, lead poisoning was diagnosed in two workmen; they showed a lead line, and blood examination revealed absorption of lead. These cases may have been due to lack of personal cleanliness and to non-observance of preventive measures. Analyses of the fris gave proportions of lead varying between 2 and 50 per cent. All the fris were easily soluble in the gastric juices.

In Great Britain the following cases of lead poisoning occurred in enamelling operations: 1909-1911, 14 cases; 1912, 5; 1913, 9; 1914, II; 1915, 5, one of which was fatal; 1916, 5; 1917, 1; 1918, 0; 1919, 1; 1920, 2; 1921, 8; 1922, 0; 1923, 4; 1924, 9; 1925, 9 (2 of which were fatal); 1926, 8; 1927, 12.

In 1923 some cases of eczema were noticed among enamellers.

A very interesting report by A. M. Anderson and T. M. Legge appeared in 1902 on the sources of danger for workmen employed in enamelling and tinning metals.

In the Netherlands in 1913, 2 cases of lead poisoning were noted in an enamel factory, where the enamel contained 0.2 per cent. of lead; 1 case in 1914, and, in 1923, 1 case affecting an enameller.

In Switzerland, in the period 1914-1915, 1 case was reported as affecting an enam-

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<table>
<thead>
<tr>
<th>Year</th>
<th>1921</th>
<th>1922</th>
<th>1923</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases of sickness</td>
<td>19</td>
<td>15</td>
<td>21</td>
</tr>
<tr>
<td>Cases of incapacity</td>
<td>11</td>
<td>19</td>
<td>15.7</td>
</tr>
<tr>
<td>Cases of incapacity per worker</td>
<td>4</td>
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<td>7.2</td>
</tr>
<tr>
<td>Cases of incapacity per worker employed</td>
<td>8.5</td>
<td>34</td>
<td>35.4</td>
</tr>
<tr>
<td>Proportion of personnel affected</td>
<td>20 p. 100</td>
<td>30 p. 100</td>
<td>37 p. 100</td>
</tr>
<tr>
<td>Proportion of personnel affected</td>
<td>69 p. 100</td>
<td>187 p. 100*</td>
<td>180 p. 100*</td>
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<tr>
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<tr>
<td>Average annual sick pay per worker employed</td>
<td>30.65</td>
<td>95.10*</td>
<td>99.33</td>
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<tr>
<td>Average annual sick pay per worker employed</td>
<td>178</td>
<td>836</td>
<td>895</td>
</tr>
</tbody>
</table>

1 Represents the estimated annual premium necessary to cover the expenses of occupational diseases.
2 The personnel employed in the manufacture of lead enamels only has been included. Percentages above 100 per cent. mean that the same workmen have been affected several times in the year.
eller in a stove factory and another case in the period 1919-1920 an enamel melter.

In the United States sanitary enamel ware does not contain lead. On the other hand enamel used for metal signs contains lead and, generally, arsenic.

The sanitary enamel ware industry, which is well developed, was made in 1911 the object of an enquiry by Dr. Alice Hamilton. She dealt with about a thousand workers, chosen from those who prepare the enamel and apply it to the metal. By means of lead test a content of lead varying from 0.51 to 20 per cent. was found in the specimens taken.

This enquiry was carried on under many difficulties on account of the great turnover among the workers, who are generally recruited from immigrants. It brought out the fact that during about two thirds of their working time the men are exposed to the inhalation of fine dust containing soluble lead.

In spite of difficulties, the enquiry permitted collected facts to be assembled relating to 217 cases of lead poisoning among 1,012 workmen examined. For the most part the workmen were enamellers.

It was not possible to carry out clinical investigation on the blood and urine during the enquiry; it had to be limited to observation of the presence of the blue line of pallor on the mucous membranes, and of the saturnine facies; and to noting what could be learned from loss of strength, and appetite, and from the existence of digestive disorders. Among the 148 workmen who during the enquiry it was possible to subject to such an examination, there were found 35 cases with signs of lead absorption, 16 with obstrunct constipation, 13 with headaches, 11 with loss of weight, 10 with nausea and vomiting, and 2 with tremors. It was found and verified that 13 workmen had had lead colic, and that 23 were in good health, but showed signs of lead absorption. In conclusion, 54, or 36 per cent., showed symptoms of lead poisoning, 56 (37 per cent.) showed no symptoms, 38 (25 per cent.) were in quite good health, but showed signs such as might be suspected to have a lead origin. Poisoning in this industry sometimes occurs in serious outbreaks. As a matter of fact, in four works in the Pittsburgh region in 1910-1912 there were 165 cases out of 385 workmen, with 11 deaths, 25 cases of paralysis and 8 cases of saturnine encephalopathy.

Leathers and Morgan had occasion to examine medically 45 workmen employed in a stove enamelling factory at Nashville, Tennessee. The management and the workmen had ignored the danger of lead poisoning to which they were exposed. Adequate measures were ultimately taken to improve the hygienic conditions of the workshops and the methods used. The enquiry disclosed that the work had been carried on under absolutely defective conditions. Of the 45 workmen examined, 19 (39 per cent.) showed distinct symptoms of lead poisoning, 11 (28 per cent.) signs which justified a suspicion of poisoning, and only 13 showed no signs of lead poisoning. The workmen concerned were aged from eighteen to forty-five years and had worked in the factory for periods varying from fifteen days to four years. The 15 workmen who showed symptoms of lead poisoning had granular redells; in 13 there had been colic and constipation; in 11 anaemia; in 8 disorders of locomotion; in 5 the lead line; in 4 a weakness of the extensors of the hand; and in 3 arteriosclerosis.

**Pathology**

Most of the troubles among makers of enamels and workmen employed on enamelling arise from lead poisoning (see article "Lead Poisoning").

Other pathological conditions, but of less importance, arise from various products used or given off in the different operations. A special place should be given to dermatitis. Leroy des Barres and Courtois-Suffit have described corrosive ulcers among enamel workers obviously due to the alkalies or acids used; and Spie-shka has also observed similar ulcers in a workman employed in cleaning articles by means of sulphuric acid applied with a brush, as well as in some women in whom the ulceration was due to debris of the materials penetrating 1-4 mm. into the skin. These lesions were situated chiefly on the sides and joints of the fingers, especially in the deep folds of the skin. In some cases the surface of the ulcers was covered with a tenacious brown crust. By their appearance, these ulcerations resembled those due to lime; but in the case in question it was not possible to determine the substance which caused them. The only thing was chemical analysis which showed a strong alkaline reaction characteristic of quicklime. The women were obliged to dip the articles to be enamelled into the cream, and they could not do this without soiling their hands. It is possible that the particles of the enamel may have entered through small lesions of the skin and caused these burnings.

Flattening of the nails of the two thumbs, as well as of the terminal phalanges from the friction of the enamel, is also reported as occurring amongst enamellers.

**Hygiene**

Fumes, danger of fire, dust, noise from grinding mills and stamps used in crushing, and the poisonous nature of some of the materials necessitate enamel manufacturers adopting a cer-
tain number of measures, among which the following be noted:

The construction of the buildings must be suitable; all openings on to public roads or on to adjoining properties must be kept closed; the walls should be so plastered that they afford a minimum of inequalities for the deposit of dust; the floor of enamelling workshops must be solid and kept in good condition; there should be weekly washing of walls and daily cleansing of work benches.

The cubic space of workplaces must be adequate; the English regulations require a cubic space of about 14 metres per person in enamelling workshops. By every means good general ventilation must be assured, either naturally or by artificial means. In the latter case the direction of the air current should be from above downwards.

As a protection against the harmful effect of dust some operations should, if possible, be carried out in the open air, or, in default of that, in closed apparatus. The use of automatic machines for enamelling, which makes it possible to carry out dangerous operations under excellent hygienic conditions, is becoming more and more general. These machines, which are of various patterns, consist essentially of a metal box divided into two parts, of which the upper part can be raised by means of a counterpoise. These divisions contain sieves full of enamel, which are brought in action by mechanically actuated agitators. The lower part is generally glazed in order that the operations may be watched. The articles to be enamelled are put on a table placed below and are arranged on a tray to which a rotary and oscillating movement can be imparted. The upper part of the box is lowered and, by means of external levers, the sprinkler is set going, and the object is turned this way and that as desired. The enamel not used falls into a hopper from which it is taken up by aspiration and returned to the upper receptacle. Attached to the upper part of the frame there is usually an exhaust chimney by which the fine dust can be discharged to the outside.

Some operations can even be done under water when there is no risk of the raw materials becoming deteriorated, such as crushing the materials used to compose the enamel.

Adequate measures must be taken to prevent gases given off from the furnaces and dust from escaping into the workshops. There must be cowlings over muffle furnaces and over enamelling tables connected with an efficient exhaust system.

The best prophylaxis clearly consists in the elimination of poisonous products and in the increasingly extensive use of leadless enamels.

Among measures of personal hygiene, the wearing of working clothes must be prescribed in the first place, especially of head coverings, which must be kept in a perfectly clean state. Gloves, which obviously might be very useful, cannot, in the opinion of workers concerned, be used on account of the short time they last and the great sweating they cause. Respirators are equally useless; at best the enameller and his assistant may be seen to protect themselves by wearing a small mask containing a sponge or simply using a moist sponge fastened before the nose and mouth.

Cloakrooms should be provided with separate compartments for town clothes and working clothes. Lavatories with hot and cold water, soap, nail brushes and towels, and also douche baths should be provided. There must be a careful cleansing of the hands and mouth before meals and before leaving work. The dining-room must be separate from the workshops; the introduction or consumption of food, drink or tobacco into the workplaces must be prohibited.

All these measures should be satisfactorily supplemented by a medical examination of the personnel on entering the trade, as well as a periodical medical examination thereafter, with power given the doctor to suspend workmen on dangerous processes who have contracted sickness.

Instruction should be given by every means, by lectures, posters and leaflets to workmen on the risks they run and the prophylactic measures to be observed.

Legislation

Young persons under sixteen years are excluded from enamelling workshops in Norway; those under eighteen years in the Netherlands are excluded from the preparation and application of enamels containing more than 1 per cent of lead by weight in the dry state; boys under fifteen years and women under twenty-one are excluded in Italy from the manufacture and polishing of enamels.

Some measures relating to enamelling have been laid down in France: the Decrees of 21 March 1914 on the protection of women and children, of 10 July 1913 on
the general hygiene of the workers, and of 1 October 1913 on hygienic measures particularly applicable to those industries in which there is a risk of lead poisoning.

In Great Britain Regulations of 19 December 1908, No. 1238, on enamelling operations and the manufacture of vitreous enamels, exclude children under sixteen years, and call for a quarterly medical examination with power for the examining doctor to suspend sick workmen. In the Netherlands the Decree of 21 August 1916 places enamels and enamelling works among the industries with a risk of lead poisoning.

Compulsory notification of diseases of the skin, both eczema and dermatitis, and ulcers of the cornea and conjunctivitis is laid down by Netherlands law; compensation is granted by the legislation which compensates lead poisoning or dermatitis (see those articles and "Occupational Diseases: Compensation").

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**Ether**

(Ester; Ethyl Ether; Diethyl Ether; Sulphuric Ether, etc.)


A large number of substances derived from alcohols by substituting acid or alcoholic radicals for hydroxyl hydrogen, are designated in chemistry under the name of "ethers".

There are to be distinguished amongst these compounds ether salts obtained from the action of an acid on an alcohol with elimination of the water and ether oxides obtained from the combination of two identical or different alcoholic radicals by one or several atoms of oxygen.

To this last group belongs ethano-oxy-ethane, better known as ethyl ether and wrongly designated in commerce in accordance with its preparation by the name of sulphuric ether.

The ethers are very stable and scarcely react in the cold with alkalis, dilute acids, sodium or phosphorus pentachloride. When superheated with water and a little mineral acid, ether is converted back into alcoholic radicals.

Methyl ether, CH₃·O·CH₃ (methoxymethane), is a gas, but liquefies at —23° and then has the specific gravity 1.617; it resembles ethyl ether. One volume of water dissolves 37 volumes of the gas, and 1 volume of sulphuric acid 600 volumes of it.

Ethyl ether. — This was prepared for the first time in the sixteenth century by Valerius Cordus from spirit of wine. It was formerly thought to contain sulphur, and was therefore given the name sulphuric ether, still in use. Its true composition was established by Saussure and by Gay-Lussac (1807 and 1815), and the constitution was enunciated by Laurent and Gerhardt and confirmed experimentally by Williamson (1851).

**TECHNICAL DATA**

Ether, C₂H₅·O·C₂H₅, is a transparent, colourless, aromatic, mobile liquid, having a characteristic odour, and a burning, sweetish taste. On evaporation, it produces intense cold. It is highly volatile and inflammable. No sparking electrical equipment should be present near its vapour. Its vapour mixed in the proportion of 75-200 mg. (of ether) per litre of air explodes violently. It is slowly oxidised by air, moisture and light to peroxides. It is soluble in twelve times its volume of water at 17° C. Its solubility in blood is practically the same as in water. It is miscible with alcohol, benzene, chloroform, petroleum benzine, and fixed or volatile oils.

It boils at 34.9° C., solidifies at —129° C. if dry, and at —40° C. if aqueous, and melts at —113° C.; it has the specific gravity 0.7196 at 15° C., 0.7196 at 15° C., 0.7289 at 6.9° C., and 0.736 at 0° C. Contamination of ether by water and alcohol may be detected at once by the specific gravity, which reaches the value 0.735 at 15° C. when the maximum proportion of water, namely 7.5 per cent., is present. Commercially the density of ether is given in degrees Baumé. It is kept in iron drums, glass bottles and tin cans.

It is obtained industrially by means of special apparatus, by dehydration of ethyl alcohol or ethanol in presence of a catalyst (usually sulphuric acid, Williamson process). The concentrated acid acting in a cold state on the alcohol gives ethylsulphuric acid and water. At about 140° C. the ethylsulphuric acid reacts on a fresh quantity of alcohol and gives ethyl oxide, at the same time effecting complete regenera-
tion of the sulphuric acid. The latter then reacts on a fresh quantity of alcohol, and the foregoing reactions occur alternatively.

As catalyst there may also be used phosphoric, arsenic, boric, or hydrochloric acids.

An ether apparatus consists of an etherifier, in which the dehydration of the alcohol in presence of sulphuric acid is effected; a saturator for neutralising the acid formed; and finally a series of rectification columns intended for the automatic separation of the ether from the dehydration water and from the non-esterified alcohol.

The rectified ether, is, after rapid examination of its temperature and specific gravity, stored in reservoirs whence it is drawn as occasion requires.

As ether vapour is much heavier than air, it tends to collect in a dense, invisible layer on the floor or bench, and may thus inadvertently cause fire or explosion.

Impurities may be the result of its manufacturing process, of ageing, particularly in incompletely filled containers, or of catalytic action of containers (such as metal). The following impurities have been found: alcohol, water, sulphuric acid, acetic acid, heavy oil of wine, aldehydes, ketones, methyl compounds, and peroxides, notably dihydroxy-ethyl peroxide (which has a pungent odour, is irritant, and very explosive).

Uses

It is used on a large scale for the manufacture of smokeless powder; artificial silk, Chardonnet process; collodion (which is made by dissolving cellulose nitrate, or guncotton in a mixture of ether and alcohol); dye solvent; solvent in perfume factories; a rubber solvent; for dissolving volatile and fixed oils, residues and balsams; for extracting the active principles from tanning substances; also as an anaesthetic; in medicine; for the dissolving of vegetable alkaloids; organic synthesis and analytical chemistry. It is also used by hairdressers for cleansing purposes and as a combustion agent in the oxy-ether blowpipe, which enables extremely high temperatures to be attained, and for forcing flowers, etc.

In powder factories technical improvements have made it possible to retard and regulate the speed of combustion of guncotton by transforming the explosive into a gelatinous substance by mixing it with alcohol-ether.

Sources of Danger

Ether evaporates speedily in open air with anaesthetic effects, also the absorption of considerable heat. Its inflammability and explosibility are very great (see above).

Cases of explosion through contact with very hot water have occurred (Berlin) and similarly, too, certain other liquids (carbon disulphide, benzene, acetone), and through contact with static electricity accumulated in machines and apparatus, etc. Even during evaporation and distillation of the ether by standing it in a recipient, there occurred (Germany, 1927-1928) explosions attributed to the formation of peroxide in the ether. Under these special conditions the heating is said to produce a violent decomposition of the ether.

Toxicity

Pure ether, but not its impurities, possesses to the highest degree the anaesthetic properties usually attributed to ether. The high vapour tension of ether causes it to penetrate tissues with ease. It first stimulates at the point of application, then depresses; and these factors account for the types of symptoms shown.

While organic degenerations are rarely caused by ether, the substance is recognised as irritating to the respiratory tract, so that pneumonia sometimes follows its careless use in anaesthesia, while nephritis is recognised as prolonged exposure.

The ethers are not altered or destroyed by contact with living tissue. Their systemic effects are as a rule greater than their action as local irritants. The secretions of the mucous membranes simply become rapidly saturated with the gas at the tension inhaled. The greater part of the irritant action occurs in the upper respiratory passages, bronchi and bronchioles, while the lung alveoli are relatively little affected. The sparing of the deeper portion of the lungs is due to the active absorption into the blood, which prevents accumulation of the irritant in the alveoli.

Henderson and Haggard state that inhalation of 35,000 : 1,000,000 of air leads to unconsciousness if continued for thirty to forty minutes. Higher concentrations produce unconsciousness in a shorter time, and very high concentrations cause death by failure of respiration. The concentration requisite in the arterial blood for the production of surgical anaesthesia is between 1.5 and 3.0 grm. per litre. The coefficient of
distribution for ether between the air of the lungs and the blood is 15. Operative anaesthesia comes in about twenty-five minutes with 3 to 4 per cent. of ether by volume in the air (formerly incorrectly stated at 7 per cent. by Boothby's method of determination); abolition of reflexes occurs after fifteen minutes with 4.45 per cent.; 6 per cent. may cause cessation of respiration after eight to ten minutes. Death is due to cessation of respiration while the heart still beats for a while.

Absorption and excretion.— Ether is absorbed almost instantly from the lungs and excreted rapidly and unchanged, and almost entirely (87 per cent.) by the same channel; traces can be found in the breath twenty-four hours after anaesthesia. A small part is excreted in the urine; the concentration of ether in the urine approaches that in the arterial blood, i.e. 1.0 to 1.7 grm. per litre. A trace of ether may be detected in the perspiration. Absorption of ether from the stomach and rectum is also very prompt and may be used for anaesthesia. The relative richness of the blood supply to the brain accounts for the rapidity of cerebral symptoms; while the last traces of ether may be looked for in the brain cavities.

Glycosuria.— Ether anaesthesia sometimes causes temporary hyperglycaemia and glycosuria, also acetonuria is frequent. Like chloroform or nitrous oxide, ether tends to reduce the reserve alkali and produce acidosis. Renal irritation, shown as albuminuria, occurs in about one-fourth of ether anaesthetics; tube casts are also common.

Those who should avoid ether are renal disease cases and those with colds and bronchitis. Also ether favours bleeding.

The autopsy in ether deaths shows nothing beyond the ordinary phenomena of death by asphyxia—heart distended, veins congested, etc. The brain cavities retain ether the longest and should be investigated in doubtful cases.

Sand was the first to conduct research into occupational poisoning by ether. He carried out experiments on animals consisting of administering to dogs in a kennel 1 cu. m. in size 500 grm. of alcohol ether in vapour form. All the dogs at first showed symptoms characteristic of incipient anaesthesia, then there was remarked acclimatisation and in the case of three dogs an increase in weight. An autopsy on two which were killed showed stasis of the organs and of the brain with fatty degeneration of the epithelium of the liver and kidneys.

From the point of view of industrial hygiene, it is the work in the manufacture of smokeless powder and of artificial silk which is of special interest. Work in the French powder factories was unpopular with the French workers, though several of them said they had become acclimatised and certain others declared that they had never felt the effects of the harmful fumes. Some workers had been obliged to quit the work; the doctors suspected that it had an injurious action on the kidneys.

The women workers seemed to be more sensitive to the effects than the men. This fact was also noted in 1918 by the British factory inspectors.

StatistieS

The average fatality is about 1 to 16,000 of ether anaesthetics administered, but varies from 1 in 5,100 to 1 in 23,200.

From the point of view of industrial hygiene it is of interest to recall the data collected in regard to the manufacture of smokeless powder and of artificial silk. In the manufacture of smokeless powder a cause of ill-health is the alcohol and ether fumes emitted in the mixing rooms where men are engaged, but also in the drawing and sorting rooms where women are occupied.

Robert has shown, in his thesis (1909), that the mixture of alcohol-ether fumes was more poisonous than the fumes from each taken separately, but much less toxic than the fumes of amyl alcohol alone.

Robert has shown, in his thesis (1909), that the mixture of alcohol-ether fumes was more poisonous than the fumes from each taken separately, but much less toxic than the fumes of amyl alcohol alone. In the atmosphere of the mixing and drawing rooms there was, according to Frois, nearly 6 grm. of alcohol per cu. m., and on this account efforts were made to recuperate the alcohol-ether fumes, which brought about a perceptible improvement in the hygiene of the mixing and drawing shops.

Grigoriev (1924) found that the minimum proportion of ether in the atmosphere of two Russian powder factories was expressed in volume 0.08 per cent. in one in summer and in the other in winter 0.007 per cent., while the maxima figures were respectively 21.18 and 2.7 per cent. This difference is explained by a series of factors: season, temperature of the workroom (+25° C. and —25° C.), apparatus, etc.

In a Belgian spinning room for artificial silk, Biot found the following rates: 0.05 c.c. per cu. m. as minimum and 0.21 c.c. as maximum.

When the weather is heavy and hot or if the windows are closed in cold weather, numerous cases of etherism are met with, the so-called "ether jag" among the workers engaged in compressing and cutting out in the powder factories where new
hands suffer from a slight form of poisoning.

Two serious cases of poisoning amongst young workers who unwisely remained exposed for six months or longer, of whom worked on eight-hour shifts. One attack.

than one attack.

the whole; 47 had had no previous factory experience; 47 had had no previous factory experience; 17 of these had had more than one attack. The first series of researches dealt with 723 workers in a factory, 388 of whom were women.

compressed and replaced by women on the operations of manufacturing foreign consumption.

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young workers who unwisely remained exposed to investigating health conditions in the three factories making artificial silk by the Chardonnet process.

To women employed up to the Armistice of 1918 and to a small group of workers considered as pre-war workers, it is admitted that modern technical methods are vastly improved. Doubts having arisen in certain quarters that conditions were far from being as good as they are said to be, the Belgian Factory Inspection Service instituted an extensive enquiry into the industry, devoting its attention to investigating health conditions in the three factories making artificial silk by the Chardonnet process. The doctor in charge interrogated and subjected to medical examination all the workers exposed to volatile fumes. The first series of researches dealt with 723 workers in a factory, 388 of whom were women. Another investigator from the medical service set himself to ascertain exactly the average concentration of alcohol-ether fumes in the atmosphere (see above).

The general data indicated with proof that the state of the health of the men and women workers in this factory could compare advantageously with that of the workers in linen factories and in rag warehouses. It is certainly necessary to take into account a whole series of factors which independently of working conditions influence the health of the staff in artificial silk factories. Data on births, still-births and infant mortality are most reassuring. As regards the artificial silk industry (see that article), it should at once be admitted that modern technical methods are very highly perfected, enabling the greater part of the alcohol-ether fumes to be captured and condensed. In this way health conditions in the industry have been vastly improved. Doubts having arisen in certain quarters that conditions were far from being as good as they are said to be, the Belgian Factory Inspection Service instituted an extensive enquiry into the industry, devoting its attention to investigating health conditions in the three factories making artificial silk by the Chardonnet process. The doctor in charge interrogated and subjected to medical examination all the workers exposed to volatile fumes. The first series of researches dealt with 723 workers in a factory, 388 of whom were women. Another investigator from the medical service set himself to ascertain exactly the average concentration of alcohol-ether fumes in the atmosphere (see above).

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Symptoms

The “ether jag” is the usual first experience of susceptible persons. It resembles acute alcoholism, except that depression follows more slowly. There are gradually increasing excitement, irritability, pugnacity or exhilaration, then confusion and drowsiness passing into stupor and unconsciousness which may be deep and prolonged, but usually the victim sleeps it off, awakening with headache, nausea, anorexia, pains in the lumbar region and general misery.

Subacute symptoms. — Alice Hamilton found also that some gave up work because of loss of appetite (which at first may be ravenous), obstinate constipation, a continual taste of ether and increasing apathy. Increased thirst, lassitude, palpitation of the heart, specks before the eyes, numbness of fingers and burning in the feet may occur. Nephritis is to be feared as a complication, and in the factory districts the physician watches for puffy eyelids, even without albuminuria, as a reason for transfer. Many become habituated, no longer have “jags,” and may gain weight, and it is thought such are not injured by continuing the work. On the other hand, many cannot become habituated.

Chronic poisoning affects the digestion and nutrition chiefly. Loss of weight and chronic constipation occur. Recovery usually follows if the exposure is stopped.

Hamilton found amongst some women workers marked eruption with itching, especially on the side of the face exposed to the cutting-out machine.

Changes in the blood have been studied by G. R. Minot. The most striking fact noted was polycythemia; 5,500,000 to 7,000,000 red corpuscles found in 38 out of 51 workers, and 7,000,000 to 7,800,000 in five other cases. In six cases only was the number of red corpuscles under 5,500,000. Among healthy women in the same locality not exposed to the action of the ether there were only found 4,700,000 to 5,300,000. The number of white corpuscles was in general normal 6,800 to 16,000, with an average of 11,000. Examination of 35 men showed only 12 with a number of red corpuscles over 5,500,000, with a maximum of 6,700,000. These examinations demand, however, still more thorough study.

Workers who have been exposed to ether inhalations may be rendered “dead drunk” after only a few glasses of beer or a single drink of whisky.
A case which came to Hayhurst's notice was that of a young man who worked in a perfumery and extract factory who suddenly developed acute maniacal symptoms after arriving home from work and died before morning from uremic convulsions.

Koelsch has also had an opportunity of studying a case of etherism of occupational origin characterised by psychic disturbances.

Hamilton mentions a man who was exposed for seven years; then because of health complaints he was shifted for the next five years and only at times exposed to ether vapours. Eventually he was compelled to stop work because of chronic interstitial nephritis. "His general condition was very poor, the urine was almost solid with albumin when heated and full of hyaline and granular casts. "He suddenly developed erythema nodosum which gradually changed to erythema bollosum and then into a typical pemphigus malignant, with blebs on nasal and buccal membranes extending down into the bronchi and finally a pulmonary edema, which was the direct cause of death.

Medical literature reveals a second case of chronic poisoning characterised by Korsakow's syndrome; a third and a fourth characterised by digestive and nutritional disturbances in general. Two other cases are doubtful.

Interesting also are the data assembled by French experts during the war amongst workers in gunpowder factories. These workers suffered from all the forms of narcosis: gradually increasing confusion, excitement depriving them for a short time of self-control, then gradual numbing of all the senses, stupor and loss of consciousness. The doctor usually arrived on the scene at the moment at which the worker had already fallen into a state of stupor. There is no treatment to be applied. The worker is simply left to sleep in the open air. Finally, if the narcosis continues the patient must be taken to hospital. Frois quotes a case in which the narcosis lasted twenty-four hours.

"The symptoms of poisoning among the workers studied by Frois were a prickling sensation with watering of the eyes; the conjunctivae may also be affected. The most significant sign is loss of appetite. It is only in case of mass poisoning that intestinal trouble is encountered — obstinate constipation, increase in volume of the liver, headache, a constant taste of ether, vertigo, trembling, very pronounced general weakness. Fatal poisoning is very rare.

"Though women have been employed in workshops (France) in which the alcohol-ether fumes were very diluted some eight cases of poisoning occurred, but of a wild form and with symptoms evincing the pathogenic influence of the ether as much as of the alcohol.

"As a result of certain complaints, it was thought that the alcohol-ether mixture might even exercise an unfavourable effect on gestation among women engaged in handling smokeless powders. A Committee of Enquiry was appointed, and in course of the first series of visits those conducting the enquiry were struck by almost entire lack of effect of the fumes where the women worked in an atmosphere charged with fumes of alcohol-ether, and especially in view of the facility of absorption of such fumes by way of the respiratory passages. Attention was then more particularly attracted by the influence of the fumes on the nervous system, on the pulmonary apparatus, on nutrition and on the genital system. The women examined belonged to different departments of the factory. Two important facts were revealed: a progressive process of accommodation sets in in the case of the woman worker, which finally gives way to anaphylaxis in the case of the experienced worker.

"During the first days the woman worker often suffers from vertigo and a sort of inebriation; this lasts for a week and then the symptoms become greatly attenuated. While these slight symptoms last it suffices for the worker to quit the workroom and breathe the outdoor air in order to cause them to disappear. In the case of a small number of workers certain other symptoms are met with, these being due to individual predisposition, thus for instance, certain workers suffer from convulsive troubles taking the form of hysterical crises and necessitating rest in the sick-room for some hours.

"One woman worker aged thirty-eight showed very clear signs of alcoholic poisoning of the nervous system by alcohol: trembling of the hands, feverish trembling of the tongue, insomnia, characteristic nightmare, anorexia, loss of weight. She was engaged in dehydration of guncotton by the use of alcohol. In drawing guncotton dehydrated by alcohol certain workers declared themselves subject to slight indispositions and nervous troubles: insomnia, excitement of a particular kind, atonach-ache, especially at night. All these troubles however passed off and they had become accustomed to the fumes. Even in the case of a pregnant worker immunity is lost. In short, real psychic troubles are only very exceptionally noted among these workers. Under ordinary working conditions the pulmonary apparatus does not appear to be affected. Nutrition seems to be affected to a slight degree by the stay in an atmosphere very slightly charged with alcohol-ether fumes. At the beginning it is slight — cramp of the stomach, feeling of nausea — but after becoming used to the condi-
tions the workers have a very good appetite, better even than is normally the case. Yet despite this excess in feeding, they show loss of weight. It is probable that the absorption of the fumes produces, despite the fact that they are highly diluted, hyperacidity, which excites the digestive system. Loss of weight may also be due to the spending of energy during long and trying hours of work.

"As regards the functions of gestation nothing abnormal was found in course of the enquiry, no disturbance being attributable to the action of the fumes. No worker suffered from metrorrhagia or menorrhagia nor from dysmenorrhoea.

"In conformity with the legislative prescriptions pregnant women were excluded from work in powder factories.

"The doctors who conducted the enquiry (Drs. Bue and Bonnaire) drew the following conclusions as the result of their investigations:

"(1) The employment of women on the manufacture of smokeless powder does not entail, unless with very rare exceptions any important troubles likely to make them quit this work.

"(2) The few symptoms of a nervous or gastric order are generally quite transitory and only appear during the first days on which they are employed.

"(3) However slightly important these troubles may seem, it may however be logically expected that they will diminish in extent with the technical progress achieved in the process of recuperating the alcohol-ether fumes.

"(4) When male labour is available it would seem advisable to abstain from entrusting the work of breaking up dehydrated guncotton to women workers.

"(5) Fecundity does not appear to undergo any change in the case of women workers exposed to emanations of alcohol-ether fumes. As a matter of precaution, however, it would be advisable to exclude pregnant women from this work." (Frois.)

**DIAGNOSIS**

The diagnosis must be made upon:

(1) a history of exposure to ether,

(2) the symptoms with or without complications as described above, and

(3) there must be differentiated: alcoholism, also bronchial, respiratory, renal, and nervous affictions from other causes.

**ESTIMATION**

An accurate method of determining small amounts of ethyl ether in air, blood, and other fluids, together with a determination of the coefficient of distribution of ether between air and blood at various temperatures, is described by Howard W. Haggard. The principle upon which the method is based depends upon the reaction between ethyl-ether and iodine pentoxide.

Detection of the ether does not present difficulty, but by reason of the extremely volatile nature of this product considerable loss of the product is to be apprehended. The odour is the best means of detecting ordinary ether, the reactions are the same as those for alcohol. In the case of qualitative research for small quantities of ether, in the absence of alcohol and other analogous products the Perrin Lallemand and Duray process may be used with advantage. When it is a case of separating small quantities of alcohol and ether from each other, it is sufficient in accordance with the directions given by Nicloux to fix the alcohol fumes by means of warm water which in the following conditions permits the ether to pass. The alcohol and ether mixture is displaced by a current of air, the alcohol is fixed by warm water, and finally the ether is condensed in very cold water.

Dosing is effected by bichromate in presence of sulphuric acid — a process which is equally applicable to ether.

**HYGIENE**

The workrooms should be constructed of incombustible materials and should be at a distance from dwelling houses. The workrooms should have effective ventilation directed downwards. The flooring should be basin-shaped to facilitate removal of liquids spilled accidentally. The ether should be manufactured and rectified in a special room entirely isolated from other buildings. The apparatus should be heated by steam or by sand baths. Vents of the hearths should always be outside the workrooms. Entry into the workrooms with an unprotected flame should be strictly prohibited. Work by daylight only should be permitted. Smoking should be prohibited and all precautionary measures against fire and against the formation of static electricity should be adopted.

Apparatus and receptacles should be carefully closed and should be airtight. In course of certain operations (spinning of artificial silk, for instance) the use of glass cases with an effective exhaust system for withdrawing fumes should be adopted. The most perfected methods of recuperating the alcohol-ether mixture should be utilized. In regard to this problem, the French enquiry of 1913 revealed the fact that the plant used at present in the powder factories is highly perfected and comprises closed apparatus.

for restricting the liberation of fumes and dust, ventilation apparatus for withdrawing to the outside air small quantities of the harmful products given off in the workrooms and even condensation systems for recuperating either the alcohol-ether fumes in the "B" powder factories or the nitrous fumes in the melinite and cresylite factories. Ventilation plant exist, it is true, in the majority of the factories, but the alcohol-ether fumes are simply driven back into the atmosphere where their diffusion gives rise to a very characteristic odour of ether. Vegetation near the "B" powder factories shows, indeed, a special colouring, blackening of the tree trunks and branches. The committee saw working at St. Médard a so-called solvent recovery plant, in which was effected condensation at the moment of drying the powder in ribbon form and which permitted of recuperation of almost half of the solvent formerly lost in the atmosphere.

The condensation of the remaining alcohol and ether fumes raises great technical difficulties. In accordance however with communications made by G. Claude to the Académie des Sciences, such condensation is not impossible in practice and can be effected economically even when the fumes are highly diluted in the atmosphere. It is, on the other hand, quite possible to conceive of apparatus for catching the alcohol-ether fumes at the points of production, before they have been allowed to become distributed throughout the atmosphere (per descensum) (see article "Solvents").

Workers should be limited to not over eight-hour shifts and a six-day week; at most, two eight-hour shifts should not be permitted together. Medical supervision with dispensary facilities and periodical examinations are necessary. Hot coffee or tea may be supplied on night shifts and during periods of high weather humidity. Workers should be supervised as to the good quality of food eaten and housing. Alcoholics should not be hired, nor those with toxic goitre (see also above, under Symptoms).

Cases which show exhilaration should be removed at once to the fresh air, then watched for depression, when stimulants in the shape of coffee, external heat, etc., should be applied. Unconsciousness demands fresh air, lowering of the head, attention to breathing, and if there is any tendency towards cessation of breathing the tongue should be pulled out, the angles of the jaw lifted and artificial respiration started. Strychnine and caffeine-sodio-benzoate may be given hyperdermically; also whiffs of ammonia to the nostrils.

To prevent ether explosions, H. Demus (1928) recommends testing the ether, before use, by means of an amido-iodised solution or mixture of titanium in sulphuric acid, which, in presence of peroxide, give respectively blue and yellow coloration. The ether if containing peroxide should be treated, by means of an acid solution of sulphate of iron (FeSO₄ + 7 H₂O), then left in contact with this solution up to the time it is needed, and afterwards distilled.

**LEGISLATION**

There is no special legislation in regard to prevention of risk from ether in industry. Evidently, however, all the measures passed for the prevention of injuries due to the toxic fumes in general, of risk from fire or explosion, likewise measures in regard to transport, storing of inflammable products, apply to those industries which manufacture or use ether.

A Royal Order of 20 September 1927 (Belgium) includes hairdressing establishments under dangerous trades when they use ethyl-ether or petroleum spirit.

Women are excluded from the manufacture of sulphuric or acetic ether and collodion in Argentina; young persons under sixteen and women under twenty-one years of age from the manufacture of ether in Belgium; under fifteen and twenty-one years respectively in Greece and in Italy. In the Netherlands employment is regulated by the Order of 1920, section 40 and schedule 33C, etc. (See also article "Solvents").

Injuries due to chloroformic ether are compensated under Swiss law. In other countries injuries due to toxic or irritant fumes receive compensation (see article "Gases (Industrial) and Fumes").

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Ethyl Alcohol
(Spirit of Wine)

French: Alcohol éthylé (esprit de vin)

Properties

Pure or absolute ethyl of alcohol, of which the formula is CH₃CH₂OH, is a colourless, very mobile liquid with a pleasant smell and burning taste. Specific gravity 0.795, it boils at 78° C., and solidifies at —118° C. Very inflammable it burns with a blue flame giving out little smoke and burning taste. It has a very pleasant smell and burns with a blue flame giving out little smoke.

The substances most used for saccharification of starch and changing the sugar into alcohol are wheat, barley, maize, rice, sorghum, potatoes, wood, etc.

Manufacture

The cereals and potatoes are treated by steam super-heated to 136° C. in a special autoclave. The brew obtained is saccharified either by the malth process or by means of acids. Sometimes wood cellulose is not used but lignin, which is found in the residuary waters of cellulose or paper factories. These waters are treated with hot sulphuric acid, neutralised almost completely by lime, then decanted and the residue passed through a filter press. The liquid is then submitted to fermentation.

If it is a question of substances containing sugar this is extracted by simple washing, pounding and expressing the pulp or by maceration. The molasses from beetroot destined for fermentation are diluted in vats with agitators, and slightly acidified with sulphuric or hydrochloric acid.

The sugary juice obtained (must) is converted into alcohol by means of organised ferments or yeasts (e.g. beer yeast) of which the principal agent is Saccharomyces cerevisiae. Under the influence of the yeast, the saccharose is first hydrolysed into glucose and laevulose, and the maltose into glucose, then the glucose and the laevulose are converted into alcohol by the zymase.

The process is in reality much more complicated; and there are also secondary fermentations yielding unpleasant products, acetic, lactic and butyric acids. But in reality it is still far from fully understood.

The ferment industry obtains to-day selected yeasts which notably improve the yield and avoid the secondary fermentations; sometimes antiseptic substances are added, such as sulphuric, hydrochloric or hydrofluoric acids. Fermentation is carried out by a continuous or discontinuous process. Certain processes employ moulds belonging to the family of the mucorines or mucors having the property of saccharifying the starch and changing the sugar into alcohol. This transformation is rather long, requiring work on aseptic lines and absence of contact of the yeast with air.

Fermentation yields juices containing 9-10 per cent. of ethyl alcohol which is separated in column apparatus ensuring a better and more complete separation of the liquids than in a simple still.

The apparatus most used to-day are those of Coffey and Savalle. The principal parts of the latter are a plate column arranged in such a way that the steam in rising cannot pass from one plate to another without bubbling through the condensed liquid, a preheater in which the liquid to be distilled becomes heated by contact with the vapours leaving the column, a cooler to condense the distilled alcohol, and a heat regulator.

Crude alcohol or low wines — obtained with the Savalle apparatus — still contain water and impurities (acetic aldehyde and its homologues, amyl alcohol, organic acids, furfurox, acrolein, ammonia, amines, etc.). The rectification of the low wines comprises at one and the same time a distillation
and washing of the vapours by alcohol itself. This is effected in an apparatus also due to Savalle, analogous to that employed for distillation, but in which two-thirds of the condensed alcohol in the refrigerator are returned to the column and traverse it from below upwards. The operation here can be continuous or discontinuous. Columns are constructed in such a way that drawings can be made simultaneously at three different levels of products of three grades — foreshots, spirit, and tailings.

Finally, various perfected apparatus effect at once distillation and rectification.

This latter process yields the following fractions: "the head", which has a disagreeable smell, containing especially acetic aldehyde and acetic ether; the alcohols of unpleasant flavour, which are distilled afresh, the alcohols of medium flavour, and the pleasant tasting alcohols which are the purest and represent 75 per cent. of the price of the liquids submitted to distillation.

The alcohols from the tailings are treated afresh, yielding the low wine oils or "fusel oil", rectification of which furnishes propyl, butyl, and amyl alcohols. Finally, the residue called "vinasse" contains a great many organic and mineral compounds, from which are abstracted notably methylamines and potash salts.

A new source of alcohol which became of importance during the war is its production by synthesis; this process, which has been employed on a considerable scale, is that which starts with acetylene and converts it into acetic aldehyde catalytically by hydration in presence of a mercuric salt in acid solution. The aldehyde is then reduced to alcohol electrolysis or catalytically by means of nickel. In France ethyl alcohol is produced by hydration of ethylene. In the mines near Bethune, alcohol is used in the manufacture of an isolating substance, bakelite, very much used in the electrical industry. The alcohol is first oxidised by heat in a current of air in the presence of copper as a catalyst. Acetaldehyde is thus obtained which, by reacting on the phenol, yields bakelite. The ethylene is furnished by the gas from coke ovens and the phenol by treatment of tars of low temperature, yielded by factories for the distillation of residues from the washing of coal.

When, in the course of the production of primary tar, a suitable coal is treated in a gas-generating apparatus, tar and gas is obtained. In treating this gas on the spot with a view to the production of alcohol, a spirit is obtained, which is easily carried and very much in demand as a carburettant.

Industrial alcohol is, it is well known, rendered unsuitable for consumption by denaturing it. Anything that denatures alcohol must have an unpleasant smell and disagreeable taste, and it ought not to be possible to separate it from the alcohol by distillation. Further, a denaturing substance should not interfere with any industrial use for which the alcohol is intended. Each state therefore applies various processes of denaturing according to the ultimate use of the alcohol. The denaturing substances most employed are methyl alcohol, pyridine, acetone, benzol, ether, etc. In Germany use is made of crystal violet; in America, of cadmium iodide, ammonia, etc. Denatured alcohol finds its most important use as a fuel combustible for motors and lighting. To use alcohol as a carburettent in petrol motors, it is necessary to add hydro carbons (benzene, toluene, xylene, naphthaline, etc.), and even ether. Thus it is that alcohol enters into the composition of several national carburettants and especially the French.

USES

Industries of the most varied character use great quantities of alcohol as much for its solvent qualities as for its chemical properties; manufacture of ether, artificial vinegar, collodion, artificial silk, fulminate of mercury and various explosives, photographic papers; preparation of tannins, chloral, lye-form; various and lacquer industries, colours, pharmaceutical products, etc.

SYMPTOMS

For injury caused through ethyl alcohol see the article "Alcohol (Intoxication by)". Here it will suffice to say a little about the use of denatured alcohol. The effects recorded by different authorities refer to different products used in denaturing; methyl alcohol, pyridine, etc. It must be acknowledged, however, that these effects are not serious except when the workmen concerned have to handle large quantities of the denatured alcohol. Although certain experts have described in the past injurious effects sufficiently serious such as nervous symptoms, headache, nausea and even blindness (Roth, according to Rambousek, and Lowy), they must be held to be of very rare occurrence to-day.
Pyridine (C₅H₅N) and methyl pyridene or picolene (C₅H₅(CH₃)N) are very powerful bases readily volatilised, even at ordinary temperature, and having a specific gravity of 115-116. These bases are given off especially in the distillation of organic substances containing nitrogen (tar, coal). Industry uses a mixture of several bases, the physiological action of which is the more energetic the higher the boiling point. The substances which interest us now are especially those of which the boiling point is round about 140°C.

The vapour of pyridine readily sets up an irritation of the visible mucous membranes (the eyes, respiratory tract) analogous to that from ammonia. When the fumes are more concentrated vomiting, diarrhoea, salivation, cramps and peripheral paralysis, etc., have been reported.

Some experts have attributed certain troubles (vomiting and diarrhoea) to the pyridine bases given off when denatured alcohol is burnt; others maintain, on the other hand, that they are due rather to the sulphurous vapours caused by the presence of metallic particles in the denatured alcohol.

Koelsch has not found the effects described among workmen using solutions, colours, varnishes, etc., containing methyl alcohol and pyridene, etc., as the denaturing agent; at the same time the workmen questioned did complain of the discomfort caused by the unpleasant odour and spoke of symptoms such as headache, conjunctival irritation, etc. Generally speaking, the symptoms were quite slight and of no importance, except in certain rare cases of idiosyncrasy.

On the other hand, cases of dermatitis are fairly numerous among workmen using lacquers and polishing materials. Such cases of eczema have been reported, for example, in Austria, in 1910, to the number of 25 among 1,328 workers; in a German factory employing 31 polishers 35 cases occurred in a period of 20 months; and in 1911, 31 among 20 women workers. Koelsch has reported twelve cases of eczema among 72 polishers and again 15 among 260. The lesions are mainly limited to the hands, forearms and interdigital spaces. Clinical appearances are not characteristic — redness, swelling, and a tendency to recurrence. Serious cases with weeping eczema, rhagades, violent irritation, etc., are comparatively rare.

Methyl alcohol, pyridene and even spirits of turpentine have been accused of causing the trouble, but account should be taken also of other causes of irritation such as the colours, mordants, oils, etc. Naturally individual predisposition plays an important rôle.

Reference should be made to the article "Alcohol Poisoning" for all that relates to the symptoms of alcoholism. Nevertheless, if it is opportune to recall here that the clinical picture from inhalation of alcohol vapour is identical with that seen in drinkers, and chronic alcoholics. As soon however as a workman combines with alcohol absorbed from vapour the swallowing of it in liquid form, he shows symptoms which do not yield to ordinary treatment.

Drinkers are generally attacked in the first few days of their employment and the symptoms are more pronounced and more easily produced amongst them than amongst abusers.

HYGIENE

The workrooms and store premises should be constructed of fireproof materials or at any rate any wooden parts should be covered by plaster or sheet iron. Magazines and workrooms should be in distinct and separate buildings and so arranged as to make supervision easy. The floor should be impermeable, of cement with sloping channels so as to direct the liquids to a cistern or cemented tank large enough to hold all the alcohol contained in the apparatus. Iron doors should open from within outwards. Casks and barrels should be so disposed as not to impede passage freely. Apparatus should be closed and capable of being worked automatically. Joints should be carefully examined for escapes at regular intervals. Metal receptacles should be placed with a distance of half a metre between them and the walls of masonry, the latter constituting with the floor a chamber covered with cement and capable of holding the whole of the alcohol contained in the tank.

All apparatus should be heated by steam; furnaces must be placed outside the rooms in which distillation is carried on. Condensation water should be cooled. Workrooms should be well ventilated; there should be plenty of daylight; if artificial illumination is required electric light should be selected; lamps, however, must always be placed outside the windows or in glass globes. Safety lamps should be used at night. No smoking or entry into the workrooms with a light should be permitted.

Fire appliances capable of extinguishing a commencing fire should be
Installed. A quantity of earth or sand proportional to the size of the establishment should be kept.

Residuary waters should be directed into the sewer.

Workmen should be drilled in the means of defence against fire and explosion. Provision for first aid against asphyxia should be made.

To the above requirements the following must be added when agricultural alcohol distilleries are in question: the fermenting vats should be placed under large hoods shepherding the gases into a tall chimney stack. Walls should be washable and rendered impermeable to a height of two metres from the ground. Floors should be washed with a hose pipe. Measures should be taken to prevent accumulation of toxic vapours, especially carbon dioxide, which might cause asphyxiation.

Effluents should be strained and purified before discharge into streams or used for irrigation if ground sufficient and suitable for the purpose is available. The residue of distillation should be diverted into watertight and covered drains.

If alcoholic vapours are simply discharged into the atmosphere where their diffusion is slow, it is easy to show that the atmosphere around the factory is rendered abnormal. The problem of condensing the fumes is, therefore, hygienic as well as economic. Great difficulties certainly stand in the way of attaining this, but a practical solution would not seem to be impossible (at least for fumes from powder factories even when these are very diluted in the atmosphere). As for hygienic measures in connection with solutions or products containing denatured alcohol, opportunity should be taken in the first place to substitute this for methyl alcohol, and in the second, to substitute spirits of turpentine for methyl alcohol wherever technically practicable. Welfare arrangements for personal hygiene of workers, such as exclusion of all kinds of alkaline soaps, good ventilation in the workroom, prohibition of use of denatured alcohol and of solutions containing it at home when work is carried on in living rooms or bedrooms, should receive attention.

Legislation

Legislation generally prohibits employment of females as well as young persons in fermenting and distillation rooms (as interpreted by statute in different countries).

Ethylene and its Derivatives


Technical Data

Ethylene, an unsaturated hydrocarbon of the aliphatic series of the olefine group, with the formula C₂H₄, is a colourless gas of peculiar rather sweet smell having a density of 0.971. It is liquefiable at 0° C. under a pressure of 44 atm. or at 103° C. at ordinary pressure. It is very slightly soluble in water and alcohol. Lighting gas contains 2-3 per cent. and to this it owes its luminosity. In its natural state it constitutes a notable proportion of the natural inflammable gases which are found combined with petroleum. Technically it is found among the gases distilled from hydrocarbons and petroleum, from shale oil, or in the course of their pyrojenous firing ("cracking") in obtaining essential oils. The most important source, however, comes from the distillation gases of coal at high temperature which contain from 0.80 to 3.68 per cent. with an average of 2 to 3 in the case of coke, and especially by carbonisation at low temperatures (between 500 and 600° C.) which yields gas having a content in ethylene of 7 to 12 per cent. An addition of half the quantity of oil to the coal to be distilled (Trent mixture) may carry the proportion of ethylene to 17 per cent.

Ethylene may be manufactured synthetically by passing a mixture of acetylene and hydrogen over a catalyst (nickel, cobalt, copper, cuprous salts) or in acid electrolytic baths containing salts of mercury. It is also made catalytically from a mixture of carbon monoxide and hydrogen.

In the laboratory ethylene is generally prepared by heating a mixture of ethyl alcohol and sulphuric acid. Other methods enable a purer product to be obtained.

The industrial importance of ethylene has only been realised recently when it began to be used in the synthetic manufacture of ethyl alcohol.

Industry obtains the ethylene required from the different distillation gases by eliminating, in appropriate manner, the impurities they contain: water (condensation by brine at low temperature absorption by sulphuric acid at 60° B., removal by liquefaction); ammonia (removal in washing appa-
Trichloroethylene is used in the following processes:

(a) In the chemical industry in the preparation of monochloracetic acid, and numerous organic synthesis: dichlorovinilic ether, employed in the manufacture of the chlorides, chloroacetyl, chloracetic ether, which is used itself in numerous syntheses, including indigo; for the extraction of fats (from bones, fish, skin refuse), paraffin, resins, stearine, vaseline; desulphurising the collections in gas cleaning; as a solvent in the colour and varnish industry; in the wine industry (distillation of wine and its residues), in the extraction of seed oil from grapes: the seeds, first dried and then crushed, are introduced into an extractor, to which trichloroethylene is added. After washing for four hours, the liquor from the extractor is distilled, whereby the oil is separated from the trichloroethylene. These processes are usually carried out in closed vessels and, apart from accidents, are unattended with danger, the more so as, to avoid the risk from the vapour, the practice is to cover the liquor with a layer of water 10 to 20 cm. in depth. The dangerous part comes in when the extracting vessels have to be cleansed and have been insufficiently freed from trichloroethylene. This cleansing process has to be done from time to time to remove the solvent from the debris of grape seeds which may be contained in it. The vessels for this reason are provided with manholes at their upper end. Steps lead down after they have been first emptied by pumping.

(b) In the extraction of flowers of pyrethrum from an oleo-resin entering into the composition of an insecticide soap. This soap, moreover, contains a little trichloroethylene which is incorporated in it in the course of manufacture.

(c) In cleaning and degreasing operations, cleaning of machinery, metal parts, cloth, glass lenses, etc.

Toxic Action

Ethylene was first thought to be an irrespirable gas. Then some experts (Tourdes, Devergie and Orfila) thought that it had a specific toxic action, which is no longer admitted now as Eulenberg, Traube and others regard this substance as harmless, although they grant that it has a slight, narcotic effect. Layet caused a dog to inhale for thirty-five minutes a mixture of 27 litres of ethylene, 10 litres of oxygen and 50 litres of air, without producing any toxic symp-
The chlorine compounds of ethylene have in general the same physiological properties as chloroform, the smell of which it recalls. These first act as an excitant of the nervous system, then later induce narcosis; they bring about convulsions, syncope, and in some cases exert a specific toxic action on the liver. According to Lehmann, the toxicity, taking that of tetrachloroethane as the standard, is of the following order:

<table>
<thead>
<tr>
<th>Substance</th>
<th>Rate of toxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon tetrachloride</td>
<td>1.0</td>
</tr>
<tr>
<td>Ethylene perchloride</td>
<td>1.8</td>
</tr>
<tr>
<td>Ethylene trichloride</td>
<td>1.2</td>
</tr>
<tr>
<td>Ethylene dichloride</td>
<td>0.7</td>
</tr>
</tbody>
</table>

From the point of view of professional risk, account should be kept of the relative volatility of these different substances. It is by no means easy to determine because of the many modifying factors: air currents, surrounding atmosphere, cooling of the liquids due more or less to evaporation, etc. According to Lehmann, evaporation in ordinary air lasting an hour of about 40 c.c. of this liquid, in a capsule of 0.5 cm. in diameter at 15° C., allows the following coefficients of relative volatility to be stated: ethylene perchloride, 3.8; ethylene trichloride, 12.4; ethylene dichloride, 37.

Trichlorethylene is said to be highly toxic and would appear to be particularly injurious to the respiratory tract, and perhaps also the circulatory system. Carriu, in experimental researches on animals, showed that a content of 146 mg. per litre of air causes anaesthesia in a guinea-pig of 600 grm. weight in five minutes and is fatal in from eleven to thirty-one minutes from general anaesthesia and respiratory paralysis. A dose of 58 mg. induces anaesthesia in seven to nine minutes, but does not cause the death of a guinea-pig of average weight in an hour. The autopsy shows generalised congestion especially of the lungs and kidneys.

Trichlorethylene also has a caustic action on the skin when it comes into direct contact. According to Koelsch, it further exerts a selective action on the sensitive trigeminal nerve without influencing the vagus or spinal nerves.

The sources of danger are represented by the industrial processes to which allusion has been made above (under Uses). It should be remembered that a mixture of ethylene and air or oxygen gives rise to explosions.

The dibromide of ethylene has led to cases of intoxication in the past when used in place of bromide of ethyl. Although not of great importance it should not be forgotten that the dibromide can — as has been said — set up poisoning. In contrast with trichlorethylene instead of dibromide of ethyl, the dibromide of ethylene exerts no sedative or narcotic action; but it causes vomiting, pallor, weakness and vertigo, etc. A fatal case has been described by Langgaard (1889). Its toxicity has been studied by Szumann (1888), Hirsch (1889) in animals (action on the heart and circulatory system; hyperaemia of the respiratory tract, of the liver, hepatisation of the lungs). Caustic action locally and corneal affections (due to the vapour) have also been described.

Recently, dibromide of ethylene has again given rise to interest because chronic effects among the workpeople who manufacture it have been observed. At present no data on chronic poisoning from inhalation of the vapour of ethylene bromide either on man or experimentally on animals are available. Kochmann (1929) made an enquiry in which he was able to reproduce the same phenomena as those observed in workmen. Inhaled, even in small doses, and from contact with the visible mucous membranes, the dibromide sets up nutritional disturbance and local irritation. The parenchymatous organs may also undergo degeneration. Death is due to circulatory disturbance mainly affecting the heart; probably also a secondary paralysis of the central nervous system (respiratory centre) occurs. The effects show themselves even with a percentage of 0.005 of ethylene dibromide.

**Statistics**

The available statistics relate mainly to poisoning by trichlorethylene.

In **Austria** several cases have been described in chemical cleaning factories.

In **France**, in 1926, 5 cases of poisoning were brought to light in a factory for the distillation of oil from grape seeds.

In **Germany** several cases were reported in 1920; 3 in 1921 (without details as to the industries or where they occurred). Between 1920 and 1922 several cases occurred among workpeople employed in removing marks imprinted on wool by means of trichlorethylene instead of benzine. (See article "Solvents"). In 1923-1924 cases of poisoning from the inhalation of trichlorethylene fumes were described as having occurred among workmen employed in cleaning out a boiler which had contained this substance; 2 fatal cases due to phosgene which is a product of the
decomposition of trichlorethylene; 5 cases (of which 2 occurred to women) among workpeople cleaning metal articles; they were affected with cardiac symptoms, vertigo, etc.

In 1925 analogous cases were described in a brewery (fainting fits, numbness necessitating conveyance to hospital). In 1926, 1 severe case was reported in a factory where a workman was cleaning metal articles by means of hot trichlorethylene; cases have been described in a wool felt works (see article "Solvents").

One fatal case was reported in 1914 in Great Britain; 3 non-fatal in 1923 following on the painting of vats in a brewery with a special varnish containing trichlorethylene. The label contained no instructions as to the danger — but merely indicated the necessity for good ventilation in using it. Since these cases occurred the factory has now issued a notice with each can. In 1925, 5 non-fatal cases from "tri" were reported.

**PATHOLOGY**

According to personal experiments effected by Davy, when proportions of 60 per cent, ethylene and 40 per cent, air are inhaled, ethylene causes vertigo, headache and loss of consciousness.

Dichlorethylene produces the same symptoms.

The pathology of trichlorethylene is more important.

In *subacute poisoning* the victim falls down as though felled like an ox. In *acute poisoning* there is time to take account of what is happening: perception of a "sugary taste" which is felt in the throat (Carrieu), pricking of the eyes, buzzing in the ears which becomes more and more intense, dulling of the senses to outside conditions, especially of hearing, which becomes faint, and a progressive sensation of numbness with absolute impossibility of being able to move. Consciousness remains, but it is impossible to act according to the will. This feeling, far from being disagreeable, is accompanied by a feeling of well-being and the agreeable sensation of irresistible sleep. Then loss of consciousness comes on and the person lapses into a state of collapse without movement or sensibility.

When no longer under the influence of the poison the subject is overcome by sleep which lasts for a more or less prolonged period. With energetic friction aided by artificial respiration the patient awakens according as the intoxication has been slight or deep. On awakening the patient is cyanosed in the face, troubled with confusion of thought, speaks with difficulty (sometimes the teeth are clenched); the eyes are closed with pinpoint pupils; in less severe cases they are open, with equal pupils, reacting to light. Sometimes the limbs are contracted with convulsive movements. Finally, movement and sensation return more or less rapidly with normal reflexes; there is a general condition of well-being in spite of great depression.

Respiration is difficult, quickened, noisy and stertorous. In severe cases as a terminal sign a cough comes on with dyspnoea and stitch in the lungs (generalised bronchitis and mucopurulent expectoration). The pulse is small and weak, showing a tendency to collapse — sometimes there is hypotension.

The digestive symptoms show themselves by bilious vomiting and thirst.

The mucous membranes of the eyes, the tongue and pharynx are red and inflamed at times.

The skin, on contact with the material, becomes erythematous and feels as though it has been burned or tickled. At once or after a varying period of time (twenty-four to thirty-six hours) according to the severity of the symptoms, vesicles appear more or less widespread, filled with a yellowish fluid, some of them tiny like needle points, others reaching the size of a five shilling piece or the palm of the hand. When the lesion penetrates more deeply attacking the derma a permanent scar remains after it has healed, while in other cases no trace remains. Sometimes similarly an herpetic eruption occurs.

In *slight cases* only loss of consciousness is observed, then on awakening, a tendency to sleep, red and swollen face, shivering fits, pins and needles feeling and redness of the skin. There is no cough, vomiting, change in the pulse or temperature. In these slight cases the only symptoms are the irritation of the mucous membranes, swelling of the pupils, and of the face and hands.

The course of the poisoning is towards a cure depending, however, on the extent of exposure to the poison. The different cases reported have been benign although only symptomatic and therefore precarious treatment can be employed. In very severe cases the patient recovers in from two to three weeks after a period of intense weakness.

General chronic poisoning has not yet been described from trichlorethylene. Mention should be made, however, of the fact that Koelsch has stated, among persons using it for ridding
metal articles of grease, persistent loss of the sense of touch, loss of reflexes in the nose and cornea, loss of taste and smell. This anaesthesia persists even after cessation of the preceding symptoms, and Koelsch states that one case was attended with trophic changes and loss of the teeth. Perhaps it should be added that these observations have led to the therapeutic use of trichlorethylene in trigeminal neuralgia. For the dibromide see above.

HYGIENE

The measures to be taken with the different substances are as follows: good ample ventilation of the premises in which the substances are manufactured; the carrying out of the different processes in closed vessels; localised exhaust ventilation to remove any fumes given off; avoidance, as far as possible, in the management of the processes of such as are dangerous, cleanliness of the vessels, as, for example, in the extraction of oil from grape seeds (employment of technical methods falling within the domain of the engineer, efficiency of filters, installation of supplementary autoclaves), etc.

Personal hygiene should include the wearing of working clothes, wooden sabots (for entering vessels containing trichlorethylene), special breathing apparatus, communicating by a pipe with the external air, etc. Instructions should be given to the workpeople (by advice, warning notices, leaflets) as to the risks run, the means of prevention and first aid. First aid should take the form of practice in removing a person affected as quickly as possible into fresh air, and in the case of actual intoxication by trichlorethylene practice in undressing the patient and warming and reviving him as rapidly as possible.

LEGISLATION

France requires compulsory notification of poisoning due to the per-, tri- and dichlorides of ethylene.

Switzerland grants compensation for illness due to trichlorethylene; likewise countries in which the diseases for which compensation is paid are, scheduled do the same.

See also articles "Solvents", "Occupational Diseases: Compensation".

Explosives


§ 1. — Black Powder


PROPERTIES

Black powder is of very ancient origin, and is said to have been introduced into Europe from China; it is compounded of saltpetre, sulphur, and charcoal, but in proportions that vary considerably. In appearance it consists of more or less regular solid particles, either fine or coarse. In olden days it was used to be pressed into such shapes as cylinders, cubes or prisms, measuring several centimetres in length and breadth. It has a density of from 1.3 to 1.8.

Powder made with graphite has a beautiful polished surface, of a gleaming greyish black colour; powder that is not made with graphite is brownish black with a tinge of grey; it is not so shiny. Black powder has a tendency to absorb moisture from the air, as it is more or less hygroscopic, depending upon the nature of the nitrate used in its manufacture. When struck between iron and iron it explodes easily, between copper and copper less easily, and between wood and wood with difficulty. If heated to a temperature of about 270° C. or if an electric spark is applied, black powder bursts into flame and explodes, giving off volumes of smoke.

INDUSTRIAL OPERATIONS

The manufacture of black powder involves several operations, the first being trituration of the raw materials. To begin with, each component is dealt with separately, the saltpetre in steel mills, the charcoal in large iron mortars with bronze pestles, and the sulphur, with a very small percentage of saltpetre, in steel mills or mortars. The triturated materials are then sifted on a wire gauze; next they are weighed and passed into leather vessels, to be thoroughly mixed together, a process lasting several hours. In order to bring the powdery mixture to a compact consistency, and the required density, it is sprinkled with about 10 per cent. of water and is compressed in bronze rolling-mills, or, which are still better, in hydraulic presses. When the compression is finished, the flat cake thus produced is broken into pieces by hand; it is then passed on to the granulating process, which is carried on in a granulating
vessel or in granulating cylinders made of bronze; there the cake is reduced to particles of the required size.

When the particles come out of the granulating apparatus they are sifted, and separated into particles that are for use, and dust. The powder is next polished for several hours in oak vessels, until it acquires the necessary hardness and polish; then it is sifted, and dried in hot-air drying chambers, and finally graphited by adding to the vessel a quantity of plumbago in the proportion of 0.1 to 0.5 per cent. Then comes “equalising” by means of two siftings: one separates the particles that are too large, and stuck together; the other, “dusting”, separates the particles that are too small and the dust. Lastly, finished batches are methodically mixed together, so as to obtain a product that is thoroughly homogenous.

Black powder is generally packed in silk or linen bags, in little packets wrapped in strong paper, or in tin boxes which are enclosed in wooden barrels or cases.

Black powder is used for military purposes and for sport, mining, fireworks, tinder, and fuses.

§ 2. — Smokeless Powder


Properties

There are two principal categories of smokeless powder: (i) powder with a nitrocellulose base, and (ii) powder with a nitroglycerine base.

Powders of the first category are composed of gun-cotton, containing about 13 per cent. of nitrogen, or of pure collodion-cotton, which contains about 12-12.5 per cent. of nitrogen, gelatinised in acetone or some other suitable solvent. Powder with a base of nitroglycerine contains, besides the nitrocellulose, from 20 to 60 per cent. of nitroglycerine. The gelatinisation of powder made with pure nitrocellulose is carried out either with an incomplete solvent, such as pyroxylene powder, e.g. English powder used in sport (E.C.), or with a complete solvent, as in the case of French military gunpowder (B).

Powders compounded of nitrocellulose and nitroglycerine can be produced in the same way, that is to say, by complete or incomplete solution, as for example the powder known as cordite; or else the gelatinisation can be carried out by dissolving collodion-cotton in pure nitroglycerine, as in the case of nitroguanidine.

Besides these two principal constituent parts, nitrocellulose and nitroglycerine, various other materials are often added to smokeless powder in order (i) to increase its chemical stability, for which purpose carbonates, diphenylamine, nitroglycerin, and substituted ureas may be used, (ii) to regulate the speed of its combustion by adding vaseline, phthalic ethers, or castor oil, and (iii) to diminish the visibility of its flame with potassium or ammonia salts.

Smokeless powder has many and varied forms; it may appear in the form of regular, solid particles, either fine or coarse, or compressed and nearly inelastic, cylinders, cubes, threads, tubes or slips, with a density from about 1.6 to 1.75. Its colour varies from yellow to dark green or brown, or even to black, according to the ingredients used.

Graphited powder is of a uniform shining black, tinged with grey, with a highly polished surface. If exposed to the humid air it absorbs about 2 per cent. of moisture. Powder with a basis of nitrocellulose is a compact substance of horny appearance; it is very hard and elastic. It is very nearly impervious to shocks; it does not ignite, nor explode, even when fired. Under the action of heat it ignites at 180° C. without detonating. In the open air it ignites on contact with a flame or an electric spark, but burns so slowly that it can be held in the hand and blown out, but, under pressure, the speed of combustion rapidly increases, and finally degenerates into a violent explosion.

Nitroglycerine powder is a compact substance, rather soft and nearly inelastic, with a sickly, burning taste; it is very sensitive to shocks; if heated to 170° or 180° C., it often decomposes with detonation. If ignited in the open air, nitroglycerine powder burns with a bright hissing flame; it cannot be blown out.

Industrial Operations

Powder with a Pure Nitrocellulose Base

Nitrocellulose that is absolutely dry is essential for the manufacture of this kind of smokeless powder. As may be seen below (see § 3, “Gun-Cotton”), the direct drying of gun-cotton is an extremely dangerous operation, and efforts are generally made to avoid it by using alcohol to displace and eliminate the water. This operation, which is called “alcoholisation”, is carried out in drying-machines, where the damp nitrocellulose is treated directly with 96 per cent. of alcohol, or by first compressing it in hydraulic presses and then displacing its humidity by alcohol in special copper cylinders, under pressures of from six to eight atmospheres of compressed air. The nitrocellulose thus impregnated with about 30 per cent. of alcohol is passed into a mixing apparatus to be gelatinised by means of a fixed quantity of
acetone or alcohol-ether, in which the stabilisers are dissolved.

The mixing process lasts from one to two hours, and turns out an absolutely homogeneous paste, which is then collected in metal cylinders, and conveyed to the “presses” where it is drawn. These presses, made of steel or bronze, are under hydraulic control; they consist of one or two main presses, which have, opening from the lower part, a pipe, which ends in an instrument appropriating the paste into the required shapes, whether threads, strips or tubes. The pressure applied varies with the hardness of the paste, and the size of orifice it is issuing from; it may reach 250-400 atmospheres. The threads, strips or tubes, in lengths, as they are formed, are carried away on a travelling band conveyer, and hung on supports, on which partial evaporation of the solvents takes place — this being called “preliminary drying”. This drying takes several hours, and still leaves 25-30 per cent. of the solvent in the product.

During all the operations at this stage of the production, considerable quantities of solvents are given off in the form of vapour, which is carefully captured and recovered, either by means of condensation effected by cooling, or by passing them into drying-machines or into a hydraulic press, where they are conveyed to other rolls which, by steam to 800° C., in order to bring evaporation, and mixing, the material is passed through steel rollers, heated by steam to 60° C. (on account of the volatility of the nitroglycerine), by blending the product methodically, and finally packing it in air-tight cases.

The mixing of the material of balistite is carried out with damp collodion-cotton, containing about 12 to 12.5 per cent. of nitrogen, which is mixed with 40-60 per cent. of nitroglycerine. The nitrocellulose and nitroglycerine are passed into a copper trough filled with warm water; compressed air is bubbled through this trough for about an hour; then the substance is passed into drying-machines or into a hydraulic press, in order to remove the surplus water. Sometimes the damp cotton is mixed with nitroglycerine and an equal quantity of water in a mixer. After preliminary drying, i.e. partial evaporation and mixing, the material is passed through steel rollers, heated by steam to 80° C., in order to bring about perfect drying and gelatinisation. After passing through the rolls about eight times, the cotton is reduced, which are placed in heated hydraulic presses, where they are made into threads, tubes or sticks, or else they are conveyed to other rolls which complete the process by reducing the leaves to the required and final thickness. Lastly, just as occurs in the case of pure nitrocellulose leaves, are obtained, which are placed in heated hydraulic presses, where they are made into threads, tubes or sticks, or else they are conveyed to other rolls which complete the process by reducing the leaves to the required and final thickness.

Smokeless Powder with Nitro-Glycerine Base

This kind of powder, as has been mentioned before, includes two quite distinct types: cordite and balistite.

Powder of the first type is made of a mixture of nitroglycerine and gun-cotton gelatinised by acetone. For its manufacture, gun-cotton containing about 13 per cent. of nitrogen is used, alcoholised in the same way as smokeless powder from pure nitrocellulose. The mixing is carried out in bronze or steel mixing-machines, which are either horizontal or vertical. The paste thus obtained is flattened into plates, or drawn out, by means of a hydraulic press, into strips or tubes, and cut into suitable lengths. Then the manufacture, like that of pure nitrocellulose smokeless powder, is completed by drying the material at a temperature which must not exceed 60° C. (on account of the volatility of the nitroglycerine), by blending the product methodically, and finally packing it in air-tight cases.

Smokeless powder is chiefly used for military purposes, or for sport.

As is the case for all other premises used for the manufacture of explosives (see § 1, "Black Powder", and § 3, "Gun-Cotton"; see also article "Nitroglycerine"), every workshop of a
powder factory must be adequately isolated, supplied with lightning conductors and fire hydrants, and surrounded with embankments of earth or massive walls. No accumulation of gun-cotton or nitroglycerine must be allowed on implements, and it is essential to clean every place and all the machinery as often and as carefully as possible.

§ 3. — Gun-Cotton


Properties

Gun-cotton is a substance the chemical constitution of which is not well defined. It represents a mixture of several nitrated celluloses. The tetranitric cellulose is represented by the formula C_{6}H_{4}N_{8}O_{16} to diodecanitric cellulose C_{24}H_{18}N_{9}O_{39}. By the action of fully concentrated nitric acid on cellulose, there results nitrocellulose of a high degree of nitration, corresponding to about 33 per cent. of nitrogen; whereas by a less intensive nitration a product of a lower degree of nitration is formed, containing 10-12 per cent. of nitrogen. 0.5 per cent. of moisture is the appearance of cotton, but it is scarcely hygroscopic at all, and is a little rougher to the touch. It has the property of easily becoming electrified when rubbed; it is insoluble in water, alcohol or ether; but it dissolves easily in acetone or acetic ether, and decomposes under the action of potassium, soda, or ammonia. In flakes or threads its density is 0.10-0.25, and in the compressed state 1.0-1.03.

Industrial Operations

The manufacture of gun-cotton consists of several processes. Absolutely pure cellulose is used, either in the form of cotton-mill waste or else of fine wood pulp. This raw material is dried in a drying chamber at a temperature of about 100° C., until it does not contain more than 0.3 per cent. of moisture; it is allowed to become quite cold, and is then passed on for the process of nitration. Here it is treated with an excess (20-100 parts for 1 part of cotton) of a mixture of concentrated nitric and sulphuric acids, in the right proportions, fixed beforehand.

The nitration is carried out either in pans or else in centrifugal nitrators, made of iron, aluminium, earthenware, or porcelain. The product is next washed several times over in cold water, to eliminate the acids. Then it is passed into wooden vats where it is washed with a solution of about 1 per cent. of sodium carbonate, and it is heated at the same time to 100° C. After this heating is finished the gun-cotton is conveyed to apparatus in which it is triturated. Here the fibres are separated and transformed into fine pulp; this is called “pulping”. This pulp is again washed, then dried by boiling in an alkaline solution which destroys the sulphuric ethers of cellulose. The stabilised gun-cotton is then washed in a special apparatus for this purpose, cold water being used; then it is “homogenised” by blending various batches; and finally it is “turbined” in order to eliminate surplus water and obtain a product containing about 30 per cent. of moisture, which can be stored without danger for an unlimited time.

Gun-cotton, in the form of hanks or flakes is used for the manufacture of smokeless powder (see § 2, “Smokeless Powder”), of celluloid, and of pyroxyldynamite (see article “Nitroglycerine”). It is compressed in the form of cartridges of various sizes for the army, navy, or mining industry. By mixing it with nitrates or chlorates of potassium or of barium, and by compressing the mixture into cylindrical shapes, nitrated or chlorated gun-cotton is prepared, and is known by such names as tonite, potentié, and canonite.

Often, e.g. for the manufacture of artificial Chardonnet silk, of photographic collodium, and of pyroxyldynamite, absolutely dry gun-cotton is essential. In this case it is dried in small quantities at a time in vacuum drying stoves, at a gradually rising temperature. Direct drying of the gun-cotton is an extremely dangerous operation; for this reason efforts are generally made to avoid it and to eliminate the water by displacement, using alcohol — the process being known as “alcoholisation” (see § 2, “Smokeless Powder”).

As stated above, gun-cotton is not explosive, and can only be ignited by the action of a detonator. Therefore its manufacture is not particularly
hazardous, so long as great care is taken to avoid all accumulation of dry nitrocellulose debris in any part of the machinery or workshops.

§ 4. — Nitroglycerine and Dynamite


Properties

Nitroglycerine (trinitrite of glycerine \( C_3 \ H_5 (NO_3) \)) is a very high explosive. It is an oily liquid, pale yellow in colour, with a density of 1.6, odourless, with a sickly, burning taste, insoluble in water, but very soluble in almost all organic solvents. It freezes about 8° C. above zero, forming tabular crystals. When it is heated to about 150° C., or is subjected to a violent blow between iron and iron, it detonates violently. If a small quantity is ignited at the ordinary temperature, it burns without exploding. It is a poisonous substance which, when inhaled in the form of vapour, or introduced into the stomach, or absorbed through the skin into the blood, causes headaches, dimness of vision, giddiness, vomiting, and even death (see article "Nitroglycerine").

The chemical composition of the various kinds of dynamite differs considerably, but they all consist essentially of nitroglycerine and of absorbents, such, for instance, as diatomaceous earth, sawdust, charcoal, and gun-cotton, often with the addition of nitrate of sodium or of potassium or of ammonia. Dynamite is of a plastic or crumbling consistency; its colour is yellowish red or black; its density between 1.4 and 1.5. It is a dangerous substance to transport; for this reason it is no longer used in its free state, but is manufactured into dynamite and smokeless powder (see § 2, "Smokeless Powder").

The Manufacture of Dynamite

The manufacture of dynamite, though it is simple, is one of the most dangerous industries. Dynamite is classed in two categories, dynamite made with inert absorbents and dynamite made with active absorbents. They are prepared by mixing together, by hand, nitroglycerine and the absorbents that have been carefully dried and measured, as to weight, in copper vessels heated by steam. In some factories the paste is mixed in kneading-troughs lined with bronze or copper. The cartridges are filled with dynamite by hand or by rotary machines, the cartridges being made of metal or of paraffined paper. The cartridges are put into well-paraffined cardboard boxes and packed in wooden cases.
§ 5. — Chlorated Explosives


Properties

Chlorated explosives are mixtures of chlorate of potassium or of soda with combustible materials, such as nitrobenzene, dinitrotoluene, mononitrophenylamine, castor oil, tar, or vaseline. The chlorates may be replaced by perchlorates. Most of these mixtures are distinguished by their capacity for extremely rapid combustion. In fact they are very destructive explosives. They are somewhat sensitive to shocks or friction. As a safeguard, the "combustible" is not mixed with the "carburant," i.e., substance that causes the combustion, until it is actually to be put to use; this is the guiding factor that controls the construction of the explosives called "Rackarock" and "Prometheus." The more modern chlorate explosives are composed of chlorate or powdered perchlorate, coated with a solution of nitrophenylamine or of dinitrotoluene in castor oil or vaseline, so that a plastic paste is formed, less liable to shocks; this is the principle of "cheddies".

Industrial Operations

In order to make "Rackarock" or "Prometheus", little cotton bags containing the carburant (which has been carefully powdered) are soaked in nitrobenzine, or in a liquid mixture of oil of tar and of sulphide of carbon. This operation is carried out immediately before it is used.

The manufacture of "cheddies" is carried out on the following principle:

The chlorate is first dried in iron drying rooms, then crushed in a metallic tun-shaped vessel in order to reduce it to fine powder. The different explosives which contain either chlorate of potassium or of soda, or perchlorate of ammonia, alone or mixed with nitrate of sodium or potassium, contain about 10 per cent. of plastic materials, such as tar or paraffin. The incorporation is carried out in an enamelled vessel, or in a cast-iron mixer, heated by steam. The plastic material is melted at a temperature of 80° C., and the powdered carburant is gradually added, the mixture being stirred for about thirty minutes with a spatula, or by machinery. Then the mass is turned out on to a smooth table, where it is triturated into a thin layer with a roller. The paste breaks up when cool, and is then granulated, sieved, and packed.

Chlorated explosives such as cheddite, markanite, steelite, minelite, or chlor-\textit{alite} are very often used in mines and quarries, and even in coal-mines where there is no fire-damp. During the war they were also used for charging fuses, petards, and even for explosive shells.

§ 6. — Nitrated Explosives


The group of nitrated explosives may be divided into three categories: nitrocarnons, nitrophenols, and nitroamides.

Nitrocarnons

Mononitrobenzene, \( \text{C}_6\text{H}_5\text{NO}_2 \), which is formed by direct nitration, in the cold, of benzene, is not explosive, and is only used, mixed with potassium chlorate, in the manufacture of some chlorated explosives (see § 5, "Chlorated Explosives"). It is a yellowish liquid, with an odour of bitter almonds, and it boils at 209° C.; it is almost insoluble in water, but is soluble in alcohol, ether, and benzene. If inhaled in the form of fumes, introduced into the stomach or absorbed into the blood through the skin, it causes headache, giddiness, and vomiting (see articles "Benzene" and "Benzene Derivatives").

Metanitrobenzene, \( \text{C}_6\text{H}_4\text{NO}_2 \), is obtained industrially by the action of a sulphuric mixture on mononitrobenzene in a cast-iron mixing vessel, at a temperature of 115° C.: the raw product is refined by crystallising it in alcohol. It takes the form of yellowish crystals, having a fusion point of 85° C., soluble in alcohol. It is employed in the preparation of explosives used in mining, especially of safety explosives (see § 7, "Ammonium Nitrate Explosives"). It has a greater toxicity than mononitrobenzene.

Trinitrobenzene, \( \text{C}_6\text{H}_3(\text{NO}_2)_3 \), can be prepared either by nitrating dinitrobenzene with an absolutely concentrated sulphuric mixture, or by oxidising trinitrotoluene with a sulphocromic mixture or with potassium chlorate in a hydrochloric solution, and transforming the trinitrobenzoic acid thus obtained into trinitrobenzene by boiling it with acidified water. When washed in warm water, dried, and crystallised in alcohol, this substance appears as yellowish crystals, the fusion point of which is 120° C. Trinitrobenzene is an excellent explosive, more powerful than picric acid; but too costly to be of practical importance (see article "Benzene Derivatives").

Mononitrotoluene, \( \text{CH}_3\text{C}_6\text{H}_4\text{N}(\text{NO}_2) \), is known in three isomeric forms: ortho-, meta-, and para-nitrotoluene; it is chiefly used in the form of a mixture obtained by direct nitration, in the cold, of toluene, for the preparation of trinitrotoluene. The three mononitrotoluenes are toxic, and produce phenomena analogous to those of mononitrobenzene.
Dinitrotoluene, $\text{C}_8\text{H}_7\text{(NO}_3\text{)}_2$, is obtained either by nitrating a trade mixture of mononitrotoluene, or by nitrating pure toluene directly. The nitration is carried out in earthenware mixing vessels, where a mixture of 7 parts of sulphuric acid, 1.5 parts of nitric acid, and 1 part of water to 1 part of toluene is treated. The mixture is continuously agitated by compressed air at a temperature of about 140° C. The result is a combination of the isomers 1, 2, 4 and 1, 2, 6, which are separated by cooling. The 1, 2, 4-dinitrotoluene is a solid product, melting at 71° C., which is used in the manufacture of some of the chlorated explosives (see § 5, Chlorated Explosives *), and the safety explosives (see § 7, "Ammonium Nitrate Explosives *"). The isomer 1, 2, 6 left in the residue is used in the manufacture of trinitrotoluene (see article "Trinitrotoluene *").

Trinitrotoluene exists in six isomeric forms. Direct nitration of toluene gives chiefly 1, 2, 4, 6-trinitrotoluene, also called tolite, trotyl, or triol, the manufacture and use of which are described elsewhere (see article "Trinitrotoluene *").

Mononitronaphthalene, $\text{C}_{10}\text{H}_7\text{(NO}_3\text{)}_1$, is obtained industrially by the action of residual sulphonitric mixtures on naphthalene in a cast-iron mixing vessel, at a temperature of 40°-60° C. Raw nitronaphthalene separates out when the compound is cooled; it is washed in alkaline water and refined by crystallisation in alcohol or benzene. The absolutely pure product crystallises into yellow prisms, melting at 58° C. The industrial product melts towards 55°-56° C. and is used in the manufacture of some of the safety explosives (see § 7, "Ammonium Nitrate Explosives *").

Trade dinitronaphthalene, $\text{C}_{12}\text{H}_7\text{(NO}_3\text{)}_2$, is a compound of three isomers: ortho-, para-, and meta-; it melts towards 140° C. It is generally prepared by nitrating naphthalene with a more concentrated sulphonitric mixture. The raw product is washed in alkaline water, and it is dried at about 50° C. This explosive is scarcely all sensitive to shocks, and it is one of the ingredients used in the manufacture of safety explosives (see § 7, "Ammonium Nitrate Explosives *").

Trinitronaphthalene and tetranitronaphthalene are obtained by treating trade dinitronaphthalene, in the hot state (at about 120° C.), with a sulphonitric mixture containing an excess of oleum. Trade trinitronaphthalene, commercially called "naphthide " or " naphthide " is a mixture of three isomers, and melts at about 110° C. The tetranitronaphthalene that is actually used is composed of two isomers, and melts at about 230° C. The two derivatives are often used in a great number of mine explosives (see § 7, "Ammonium Nitrate Explosives *"); see also article "Naphthalene *").

NITROPHENOLS

The three isomeric forms of mononitrophenols, $\text{C}_6\text{H}_4\text{(OH)(NO}_3\text{)}_1$, are not explosive. The three recognised dinitrophenols, $\text{C}_6\text{H}_4\text{(OH)(NO}_3\text{)}_2$, detonate easily in the form of metallic salts (chiefly those of lead and silver), and yet they are sometimes utilised in the preparation of primers. The most important of the ordinary nitrophenols is 1, 2, 4, 6-dinitrophenol, which is described in the article "Picric Acid " (see also article "Dinitrophenol *").

Trinitroresol, $\text{C}_6\text{H}_4\text{(OH)(NO}_3\text{)}_3$, is an explosive very similar to picric acid, and is a combination of isomers melting at 105°-106° C. It is manufactured in the same way as picric acid (see that article). As cresylite *, it is used for loading shells, and sometimes as well — in the form of metallic salts — in the preparation of primers. As a military explosive, 40 parts of pure picric acid (melinite) are mixed with 60 parts of trinitroresol, and a thoroughly plastic substance is obtained at a temperature of 65°-70° C. It melts at about 85° C., which makes it valuable for loading shells. This or pure cresol-nitrophenol cresylite 60/40 ". In addition to pure cresylite, its salts are used for loading shells, chiefly cresylate of ammonia, which is known as "ecrasite ".

Pure trinitrometacresol is very similar to picric acid; and melts at about 105°-106° C. It is soluble in water and in alcohol; it is sensitive to shocks, especially if it is in the form of metallic salts.

Trinitroresorcine, $\text{C}_6\text{H}_4\text{(NO}_3\text{)}_3\text{(OH)}_1$, known as oxyopic acid, is obtained by the action of a sulphonitric mixture on resorcine; it gives very explosive salts, which detonate easily under a shock or friction. It is used in the manufacture of primers, as a substitute for fulminate of mercury. Pure trinitroresorcine is a microcrystalline substance yellowish in colour, and is insoluble in water, but soluble in alcohol and ether.

Trinitrophloroglucine, $\text{C}_6\text{H}_4\text{(NO}_3\text{)}_3\text{(OH)}_1$, is obtained by nitrating with sulphonic acid pure phloroglucine or phloroglucinol, of which potassium and lead are used in the preparation of primers, as a substitute for fulminate of mercury. Pure trinitroresorcine is a microcrystalline substance yellowish in colour, and is insoluble in water, but soluble in alcohol and ether.

Nitroamines

Tetranitramine, $\text{C}_6\text{H}_4\text{(NH}_3\text{)}_4$, is formed by the direct action of concentrated sulphonitric mixture on metanitramine; and melts at about 150 per cent. It is not often produced industrially on account of its costliness. It is a crystalline yellow powder, with a fusion point of 82° C.; it is insoluble in water, and slightly soluble in alcohol or benzene. When heated it detones violently at about 230° C.

Tetranitromethylaniline, $\text{C}_6\text{H}_7\text{(NO}_3\text{)}_4\text{NHCH}_3$, is prepared by treating sulphate of monomethylaniline with a concentrated
sulphonitric mixture at a temperature which does not exceed 50°C. It forms colourless crystals, melting at 132°C, insoluble in water, but soluble in hot alcohol and in benzene. It ignites if heated to 185°-195°, and is more sensitive to shocks and friction than is picric acid. The strength of this explosive is great, and much superior to that of gun-cotton, trinitrotoluene or picric acid. As * tetryl * it is used for the manufacture of some detonating fuses, and detonators.

Hexanitrodiphenylamine, \((C_6H_4(NO)_2)_3\) NH, also called * hexamine *, is obtained by treating diphenylamine with sulphonitric acid or, better still, by condensing dinitrodiphenylamine with aniline, and by nitrating the resultant dinitrodiphenylamine with pure nitric acid at a temperature of 80°-90°C. The raw product is filtered, washed in nitric acid to eliminate the tarry exudates, and then is boiled in warm water until a neutral reaction is obtained. Hexamine is a yellow, microcrystalline powder, almost insoluble in most organic solvents, and insoluble in water; but it is quite soluble in aqueous solutions of potassium hydroxide, soda, or ammonia. It ignites at about 250°C, without having first melted. Hexanitrodiphenylamine and its metallic salts detonate under the effect of shock or friction more easily than picric acid.

Hexanitrodiphenylamine and its salts are very poisonous, and may frequently cause very serious dermatitis (see article * Skin Diseases *).

§ 7. — Ammonium Nitrate Explosives


**Properties**

The principal characteristics of these explosives are: safety in their manipulation, low temperature of explosion, and the great volume of their explosive gases which are free from carbon monoxide. For this reason this category of explosives is recommended for use in mines where there is fire-damp. They are called * safety explosives * and * anti-gas*. They are divided into three categories, according to the combustibles used for their manufacture.

Ammonites contain aromatic hydrocarbons and usually their nitro derivatives, e.g. dinitrobenzene, di- or tri-nitrotoluene, and mono-, di-, tri- and tetranitronaphthalene; sometimes a small quantity of gum-nitration is added, or nitroglycerine, together with fine sawdust. The explosives of this category look yellow or brownish-yellow, and may have a powdery or plastic consistency: sometimes they are compressed into granules, or straight into cylindrical cartridges.

Ammonals are composed of nitrate of ammonia with such metallic powders as aluminium, zinc or ferrosilicon; and are fine greyish powders.

Dynamites are essentially powdered brown coal, mixed with nitrate of ammonia. They always appear in the form of an extremely fine powder, of light colour, varying from yellowish to brownish.

All explosives made of ammonium nitrate may be thrown into the fire, where they will burn quickly without fear of detonation. They are very resistant to blows from a hammer or to rifle bullets, and they can only be made to detonate by a very strong detonator made of fulminate of mercury. Explosive mixtures with a nitrate of ammonium base are hypsographic, so that if exposed to a damp atmosphere they very soon lose their potency.

**Industrial Operations**

The manufacture of ammonium nitrate explosives is very simple and not attended with much danger. The first operation is to dry the ammonium nitrate, and then to triturate it either by itself, or with the addition of a small quantity of charcoal, in steel or bronze mills, which are heated to a temperature of 70°-80°C. Then the materials, now as fine as possible, are mixed with the combustible. This operation is carried out in the same mills or in similar vessels to those used in the manufacture of black powder, varying according to the nature of the substance that is added (see § 1); sometimes, and this chiefly in the preparation of compounds of nitroglycerine, the mixing is carried out in mixing-machines similar to those used in the manufacture of smokeless powder (see § 2) or of dynamite (see § 4). The materials, now absolutely homogeneous, are dried at about 60°-70°C for several hours, and they are sieved over a metallic gauze and passed on to be put into cartridges. This last operation is carried out either by hand, using rotary stubbers, or by special automatic machinery, according to the consistency of the substance.

Paraffined paper is used; the cartridges are put in cardboard boxes that have been thoroughly paraffined, in order to keep the damp out, and then packed in wooden cases.

Ammonites, such as Favier powder, naphthalites, densites, fulminates, astralites, bellites, nobelites, and tincalites, are used almost exclusively as safety explosives in mines where there is fire damp; whereas ammonals can only be used in these mines if they do not contain more than 6 per cent. of aluminium at the most. Ammonals,
such as A and B ammonials, westphalite, anagon or ripping-ammonial, are generally used in mines that are free from fire-damp, and in quarries. During the war ammonials, either by themselves or mixed with trinitrotoluene, e.g., the English “amatol”, were used for loading hand-grenades. Dynamite is the explosives specially used in mines where there is fire-damp.

§ 8. — Use of Explosives

French: Emeplot des matières explosives. —
German: Anwendung der Sprengstoffe. —
Italian: Impiego degli esplosivi. — Spanish: Aplicacion de explosivos.

Explosives are generally used in three different forms: ballistic powder, warfare explosives, and industrial explosives.

BALLISTIC POWDER

Charges of black powder or of smokeless powder for rifles and small calibre guns are enclosed in a brass case, in which the projectile is inserted. The whole thing constitutes a cartridge.

In the case of guns, the calibre of which is more than 10 cm. or thereabout, cases are also used, with a separate projectile, the shells being closed with a disc made of brass or papier mâché, and absolutely air-tight; the charge is generally enclosed in the shell in one or more little woollen or silk bags, so that it is possible to make the charge larger or smaller just before firing. The primers of rifle cartridges, which are composed of copper or brass caps containing fulminate of mercury, are fixed in the end of the case.

Artillery shells have more powerful fulminating primers, containing in the front a small charge of fine black powder. In the case of old-fashioned guns (cannons) the charge is enclosed in a silk bag called a "cannon-cartridge", and is fired by means of a friction-tube.

Lead cartridges used in sport have a percussion cap fitted into a brass or copper end to which is fixed a resistant cardboard jacket. The powder is inserted into the base of the case and covered with a wad, which is, in its turn, covered with the shot, and closed with a round cardboard shield to which the edges of the jacket are fixed.

EXPLOSIVES USED IN WAR

The chief military uses of explosives are as charges for rifles, shells, torpedoes, hand grenades, aeroplane bombs, destructive petards and for the sappers’ military mines.

(1) The charge for rifle bullets is generally made with fulminate of mercury, combined with a small charge of some destructive explosive of picric or some other acid. Luminous explosive projectiles are generally used in order to check the range of the rifles at night.

(2) Artillery shells are of three kinds: shrapnel, destructive shells, and gas shells.

(a) Shrapnel, or shells filled with shot, are intended for firing into troops. The iron body of shrapnel has at the back a charge of black powder or smokeless powder. The remaining space is filled with lead bullets plunged in a mixture of sulphur and coleophor or of asphalt, and this is closed by the fuse. This fuse is of a most complicated construction, and ignites the priming either, within a regulated time, by opening the fusing tube, or when the projectile suddenly slows down in its course, whilst a small, mobile mass controls the shock of a striker against the priming.

(b) Explosive shells are used when obstacles have to be demolished or breaches opened up. The body of this projectile is made of cast-iron, and trinitrotoluene, picric acid, melinite, or cresylite are used for its charge, as these substances have the advantage of being both very powerful and fairly insensible to shocks. The shells are plated with pure tin or they are japanned; then they are heated, and the explosive, in a melted state, is poured in at a suitable temperature (150° C. for melinite or 80° C. for tolite).

The tube of the funnel which is used in the filling serves as the mandrel to reserve space for the secondary detonator; this is composed of a cylindrical cartridge of compressed, powdered melinite, or of fine, special smokeless powder, communicating directly with the priming system.

The difficulty of charging with explosives in the melted state makes the use of microcrystalline or amorphous plastic explosives preferable, in which case the charging is carried out with much less danger, simply by compression in the cold state.

(c) Gas shells are the most modern form of munitions, which make it possible to use poison gases of great intensity.

The gases used in warfare include a long list of gaseous substances or volatile liquids. Examples are: simple chlorine (Cl); phosgene (COCl₂); the chlorated methylic ethers of formic acid, such as "palite" and "surpalite"; the chlorated or bromated acetones;
bromide of benzyle (C₆H₅, CH₂, Br), known as "camite"; chloropiridine (CCl₃, NO₂), known as "aquinite"; hydrocyanic acid (HCN), known as "vincentite"; the chlorated or cyanided methyl-, ethyl-, vinyl- or phenyl-arsines, such as "levisite"; yperite (Cl₂, C₆H₅, S, C₂H₂, Cl); and many others.

The old way of using poison gases was to let them escape slowly in the shape of a cloud streaming out from a number of steel containers. But it is more economical, and surer, to use gas shells in grenades or shells, which are thrown by hand or from guns. The construction of gas shells is similar to that of explosive shells. The body of these shells is divided into two parts, entirely separate one from the other; the first is the larger, and is filled with a poisonous substance, either in the form of compressed gas, or its solution in a liquid state, or even solid; in the other part of the shell, forming its cap, is placed the fuse, in the same way as the fuse of an explosive shell or of shrapnel.

The filling of gas shells is a very dangerous operation, and must be carried out in special buildings provided with a perfect ventilation system.

(3) Torpedoes are generally charged with compressed gun-cotton in a moist condition. Extremely highly nitrated nitrocellulose is used for this purpose; it is compressed in a damp state under great pressure, by means of the hydraulic press, into the required shape. The charge is ignited by a secondary detonator of dry gun-cotton, which is primed with fulminate of mercury. Besides gun-cotton, tolite or even dynamite is used for charging torpedoes.

"Sleeping (dormant) mines", "wet torpedoes" and "automatic torpedoes" are distinguished one from another according to the use to which they are to be put.

(4) Hand grenades are small, hollow iron globes or boxes filled with powder, tolite, melinite or ammonal, and supplied either with a fuse or percussion-cap. They are either thrown by hand, or from a service rifle.

(5) Aeroplane bombs have an iron body weighing from ten to several hundred kilograms, filled with tolite, melinite, cresylite, or hexamine, and supplied with a fuse like shrapnel.

(6) Destructive petards or explosive cartridges are useful for causing explosions, when mines cannot be laid beforehand. They are prismatic or cylindrical boxes, made of iron or brass, plated inside and japanned, and charged with dynamite, melinite, or melted ecrasite. The lid is soldered with tin on to the box, and has a socket inside, in which is the detonator.

(7) Mines used by military engineers are mechanisms, often prepared in peace-time, for destroying railway tunnels, piers of bridges, or to plough up the ground at certain points. They take the form of metallic boxes charged with several kilograms of black powder, melinite, ecrasite or tolite in the melted state. Their priming is effected by means of fuses or detonators, or they are brought into action by an electric spark.

**INDUSTRIAL EXPLOSIVES**

Explosives are used for works of demolition of very diverse kinds, e.g. in working mines and quarries, in piercing tunnels, in submarine works, in tree-felling and rooting up stumps, in clearing uncultivated ground, for removing ice-floes, and breaking up ice.

Whenever a breach has to be effected, a drill-hole for a mine must be pierced by hand or by machinery; the holes are carefully cleaned out, then cartridges of the required diameter are inserted one by one, and each one is pushed home as far as possible with a wooden tamping bar. The detonator is fixed in the last cartridge; then the remaining part of the hole is stuffed with sand, and arrangements are made for firing the charge. This may be effected either by means of a fuse which is ignited with a lighter, or by means of electric firing which is worked by an electric spark, or by a quick-match, using either friction or percussion.

Charges of black powder can also be ignited directly just by a fuse, without using a detonator; whereas all other explosives, e.g. dynamite, gun-cotton, chlorated explosives, and ammonium nitrate explosives, can only be used by means of a detonator or a detonating fuse.

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**§ 9. — Fireworks**


**PROPERTIES**

Pyrotechnical products vary considerably; they may be divided into three chief categories: fireworks; primers and detonators; igniters and detonating fuses.

Fireworks are extremely inflammable mixtures, of similar composition to that of black powder.
Primers and detonators generally contain fulminate of mercury, and as their manufacture is a very delicate process, the same precautions are necessary. Igniters are made of black powder; and detonating fuses are generally filled with fulminate of mercury. (As to the properties of these products, see articles "Primers" and "Fulminate of Mercury").

**INDUSTRIAL OPERATIONS**

**Fireworks.**—The material generally used for the manufacture of fireworks is priming-powder, or pulverised black gunpowder. Associated with this powder there are used: "comburants", or supporters of combustion, such as nitrates, chlorates, perchlorates, picrates, and gun-cotton; combustibles, such as different forms of coal, tar, paraffin, sulphur, sugar, phosphorus, and powdered metals; such colouring matters as salts of sodium, potassium, calcium, barium, strontium, and copper; incandescent materials, like silica, kaolin, and mica; and, as binding materials, gum arabic, resins, and gums. These substances are triturated, and thoroughly mixed either in the dry state or else by a moist process, by hand or by means of suitable machinery; and finally they are loaded into tubes of either cardboard or metal. They are primed by means of a fuse, and are projected either by hand, or by using a rifle or mortar.

Fireworks also include luminous fire (in the form of fire-balls, gas-rockets, incendiary rockets, life-saving rockets, marine signals and signals of distress, railway fog-signals, coloured lights, star shells, Bengal fire, and army signals), luminous powders used in photography, and pyrophoric powders which burst into flames when in contact with the air.

**Primers and Detonators.**—The object of primers is to ignite charges of powder, and that of detonators to discharge mine explosives. They consist of little copper or brass tubes containing mixtures of fulminate of mercury with black powder, some nitrate or chlorate, sulphide of antimony or powdered glass. Sometimes this mixture is laid on picric acid, tetryl or tetryl. Manipulation of the mixture, whether dry or moist, is carried out in small quantities at a time, in workshops where the ground is carpeted, the tables are covered with felt, and the men are provided with felt shoes. Each quantity is sifted and pressed through a hair sieve. The drying-process takes place at a moderate temperature; filling is carried out in moulds with a separate lever for each of the capsules. The strictest precautions are taken to avoid all shock and friction during the work, and above all to prevent any accumulation of dust in any part of the machinery or workshops.

**Igniters and Detonating Fuses** (slow and quick fuses).—Mine fuses, which are used for blowing up mines, are manufactured by distributing black powder at the rate of about 5 grm. to the metre, in an enveloping tube composed of a few threads of jute; a few threads of cotton are twisted several times round the fuse, and if necessary are covered again with one or two strips of calico. Ordinary fuses are stuck together with paraffin, and covered with talc or kaolin powder; tar fuses are impregnated with tar or asphalt; gutta fuses are covered with gutta percha, applied by stretching; and safety fuses are made fireproof by impregnation with phosphate or of silicate of sodium.

Reference must also be made to the manufacture of tinders for miners' lamps, for which it would appear very difficult to avoid the use of white phosphorus.

Detonating fuses (quick fuses) are made in the same way as slow fuses, i.e. by enclosing a thread of fulminating mixture in a double or triple fabric, or by filling a tube of tin or lead with gun-cotton, picric acid, or tetryl.

Slow and quick fuses are generally sent out in barrels, containing from 200 to 250 rolls, each composed of from 8 to 10 metres. A slow mine fuse should burn steadily at a rate of 93 seconds per metre and is powerful enough itself to ignite black powder; but in the case of high explosives a fulminate of mercury detonator must also be added. The speed with which the detonation of a quick fuse travels is between 5,000 and 7,000 metres per second, so that this can be used by itself directly to ignite each charge of high explosives.

During the manufacture of slow and quick fuses, when extremely inflammable or explosive substances are handled, e.g. black powder and fulminate of mercury, naturally the same precautions must be taken as in the manufacture of these explosives themselves (see § 1 above and article "Fulminate of Mercury").

**Dangers**

The industrial processes which are considered above involve a large number of occupational dangers which arise from the various products manipulated or manufactured, as well as
from the substances which are liberated in the course of chemical reactions. There may be mentioned nitric and sulphuric acids, sulphurous anhydride, the mixed acids, benzene, its homologues and their nitro- and amido-

derivatives, nitrobenzene, nitro-aniline, nitro-toluene, nitrobenzene, nitro- and chloro-
derivatives, and trinitroaniline, fulminate of mercury, acetone, amyl acetate, white phosphorus, chlorine, alcohol, ether, chromates, chlorates and nitrous gases.

Facts relating to physiological and pathological reactions, to the incidence of danger, and to hygienic measures are dealt with in the corresponding articles.

The French Commission appointed in 1907 to study the question of ameliora-
tions in the powder industry, especially from the point of view of the workers' health, laid the results of their investiga-
tions before the expert, Courtouis-Saffit. He has published a special work on the subject and this contains a résumé of the types of disease that may occur in the course of the manufacture of powders and explosives.

He refers to illness caused by various kinds of dust, from coal, sulphur, and saltpetre in the course of the manufacture of black powder. According to the medical evidence, it seems that workmen who manipulate black powder are not affected by coal dust to any greater extent than are other workmen; and it also seems that dust from sulphur only causes irritation of the mucous membranes, and that as an exception; and in any case that these affections do not last long. The occurrence of perforation of the nasal septum, reported among workmen at powder factories, and called "gun-
powder makers' ulcer", has not been confirmed by later investigations.

The symptoms which are observed among workmen employed in the manu-
facture of powder made with bi-
chromate are characterised by lesions of the skin and mucous membranes, especially the nasal mucous membrane (see article "Chromium and Chrom-
ates"). The respiratory and upper digestive mucous membranes likewise are often affected by bichromate dust.

In handling chlorates there is not only serious danger from clothes, impregnated with chlorates, catching fire, but also danger from reactions with the mucous membranes leading to ulceration and perforation, just as in the case of chromates (see article "Chlorates").

Nitrated explosives — apart from the typical action of nitrous fumes — are very apt to cause unbearable irritation of the respiratory mucous membrane, and it is impossible to work without a protective mask, even for a few minutes. Men in contact with melinite and cresylite for some length of time are apt to complain of gastro-intestinal trouble, especially of vomiting and yellow-coloured diarrhoea. A more fre-
quent trouble is a peculiar yellow colouring of the skin which is affected with a serious form of pruritus. The temperature runs high, and the pulse is quickened.

Reference should be made to the special articles so entitled for troubles arising from fumes, e.g. alcohol, ether, nitrous gas, and benzene derivatives. The symptoms observed to result from the inhalation of alcohol and ether fumes among workmen exposed to their inhalation are the same as those observed in men who are the subjects of chronic alcoholism through drink-
ing. It is of course a difficult matter to apportion the blame for these symptoms between the inhalation and the ingestion of alcohol in the case of these workmen. However, daily prac-
tice has born out the fact that if the workman is a drinker, the usual treatment used in the case of inhalation of alcoholic fumes has very little effect, or even none at all. The workman who is a drinker is seriously affected at the outset; he is tormented with an unquenchable thirst. The disorders are more accentuated in the case of drinkers, and whereas the man who has been poisoned only by the fumes recovers quickly when the cause is re-
moved, the drinker continues to display the same train of symptoms. Several publications on the action of alcohol and ether fumes have appeared: by Robert (1909 thesis), Frois (in France), and Hamilton (in the United States). This subject is dealt with in detail in the article "Ether".

The toxic effect of gases liberated by explosives in confined spaces is, of course, more important than the effects of an explosion in the open air.

Several explosives liberate consider-
able volumes of carbon monoxide, up to 30-47 per cent.; others liberate sulphur-
phurous anhydride, from 5-15 per cent., or nitrous oxide.

The chlorated explosives which were so extensively used in the war, and are still used on account of their cheapness, have caused a great many fatal acci-
dents in Germany.

The effects of these explosives make themselves apparent in headaches, weakness, giddiness, vomiting, and, in time, in irritation of the respiratory
passages. Yet examination of the blood has never shown much evidence of the presence of carbon monoxide.

Chlorated explosives liberate very little carbon monoxide, but when they are mixed with nitrated compounds they give rise to small quantities of oxidising gases, such as nitrous fumes. Solid particles of alkaline chlorides and black smoke present in the gaseous clouds increase the irritant action of the oxides of nitrogen on the respiratory passages.

As a result of enquiries made, Hamilton was able to draw up the following statistics dealing with cases of poisoning reported in twenty-eight American munition factories during the year 1916:

<table>
<thead>
<tr>
<th>Nitric acids and oxides of nitrogen</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trinitrotoluene</td>
<td>1,389^24</td>
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<tr>
<td>Picric acid</td>
<td>668^11</td>
</tr>
<tr>
<td>Nitroglycerine and nitrobenzene</td>
<td>192^1</td>
</tr>
<tr>
<td>Benzene and toluene</td>
<td>147^1</td>
</tr>
<tr>
<td>Sulphuric acid</td>
<td>101^1</td>
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<td>Aniline</td>
<td>205</td>
</tr>
<tr>
<td>Phenol</td>
<td>205</td>
</tr>
<tr>
<td>Sulphuric acid</td>
<td>205</td>
</tr>
<tr>
<td>Mixture of acids</td>
<td>205</td>
</tr>
<tr>
<td>Chlorine</td>
<td>205</td>
</tr>
<tr>
<td>Ammoniac</td>
<td>205</td>
</tr>
<tr>
<td>Mercury</td>
<td>205</td>
</tr>
<tr>
<td>Pulminate of mercury</td>
<td>205</td>
</tr>
<tr>
<td>Nitronaphthaline</td>
<td>205</td>
</tr>
<tr>
<td>Total</td>
<td>2,425^21</td>
</tr>
</tbody>
</table>

Note.—The figures in small type indicate the fatal cases.

Literature reveals a great many cases of conjunctivitis, blepharitis, keratitis, and especially dermatitis, due to the manipulation of explosives and especially of an explosive called "Tri-westphalite" (Breslau, 1921). Two cases of poisoning by "cheddite", which is TNT with a chlorate, have also been reported, but it was really due to accidental ingestion of the explosive (Reach, 1919). In Germany, in 1921, a case of cancer was reported in a gunpowder maker, who had been in contact with aniline. But the general opinion is that this was merely a coincidence.

In France, Debat drew attention in 1915 to dermatitis occurring among workmen employed in making fireworks and those men who handle fulminates. The dust and fumes produce: a canary yellow colour in the hair and skin, specially of the uncovered parts; an irritation of the mucous membranes, with watering of the eyes, sensations of having grit in the eyes, and redness of the conjunctivae, which, however, may improve or disappear completely in two or three weeks; sneezing, running at the nose, and epistaxis; a bitter taste in the mouth, nausea, and loss of appetite; cough, a burning taste in the mouth, and a sensation of constriction behind the sternum; frequency of micturition and erections; and also dermatitis, in the case of a minority of the workers, which appears on the uncovered parts of the skin ten to twenty days after commencing work. The dermatitis was polymorphous, with erythema, papulous eruptions, eczema, and pustules; it was accompanied by oedema of the face and genital organs, and was followed by desquamation of the skin.

In the work published by Mr. Frois in 1926 called Santé et travail des femmes pendant la guerre ("Health and Work of Women during the War"), there is some interesting information about occupational poisoning due to munition work: nitrous fumes, nitrated and chlorinated derivatives, trinitrophenol, benzene and its derivatives, nitrated xylene and nitrated naphthalines, nitrated toluenes, tetrachlorethanie, alcohol-ether fumes, nitroglycerine, salts of mercury, and white phosphorus (see these articles).

Emma Ward has studied the risk of necrosis of the jaw caused by phosphorus among men and women who work in fireworks factories. An enquiry was held into 14 cases, 2 of which were fatal, reported among 366 workpeople, 185 of whom were women, employed in three American factories; but, of these 366 persons, only 71 were in contact with the white phosphorus; 56 were females, 3 under sixteen years, and 15 were males, 1 under sixteen years. Most of these persons were entirely ignorant of the danger to which they were exposed. According to Ward, the industry which nowadays most exposes workers to phosphorus necrosis is the manufacture of fireworks with a phos-
when interviewed by Vai-d, necrosis, and one of the manufacturers, prohibiting them. and have considered the question ported, of the little fireworks made for children and the Labour Department to obtain the prohibition of the use of white phosphorus in the manufacture of fireworks. Cases of phosphorus poisoning have also been reported among workmen who make the tinders for miners' lamps. Nitrohydric acid, NH, not long ago (1927) caused poisoning in the case of a chemist, who showed symptoms of mild anaemia and albuminuria. The case, reported by Stern, gradually recovered. The salts of this acid are very explosive and extremely dangerous to handle. Nitride of lead is used for priming the detonators of explosive cartridges.

HYGIENE

The object of hygienic measures is to bring about improvements even in cases where the dust liberated is not considered to be very harmful, coal dust for instance. The problem is a difficult one, owing to the explosive properties of these various kinds of dust, which are similar to those of black powder, with danger of conflagration from impact, friction, or a rise in the temperature. In these cases hygienic measures might only be effected at the expense of personal safety.

However, technical science has found a means of solving this problem by adopting methods which prevent the liberation of dust by using hermetically closed apparatus, by avoiding any rapid movement of the materials or the dust, by effectively removing by suction the dust at the exact spot where it is produced.

Without entering too much into detail, there are certain points which must be borne in mind: mechanical ventilators must not be used on account of danger of explosion, but steel flues with a single airshaft, as the dust from powder easily clings to any surfaces which modify the direction of the draught. Tinplate must not be used, nor must solder be composed of tin, since nitrate of tin may form, which is inflammable; but copper pipes welded together must be used.

Exhaust draughts must be effected by steam, water, or compressed air; the last named is most to be recommended.

Alcohol and ether fumes should not be allowed to escape into the atmosphere, for it is absolutely essential that operations in which they are liberated should be carried out in apparatus that is hermetically closed, and associated with recovery of the solvent. The workshops where the cutting and sorting goes on should be frequently cleared of dust, so as to reduce to a minimum the liberation of "etheral" fumes. Drying-rooms can easily be made healthy, for the operations of charging and emptying can be carried out automatically, without any of the staff being exposed to the harmful influence of a heated atmosphere, loaded with poisonous fumes.

As regards other substances, the reader is referred to the appropriate articles. Referring to the use of white phosphorus in the manufacture of fireworks, Ward's opinion is that it is absolutely necessary to adopt measures similar to those used in phosphorus factories if cases of necrosis are to become of less frequent occurrence, viz. effective ventilation and elimination of poisonous fumes, which should be caught at the place where they are formed; very strict regulations as to personal cleanliness; periodical rotation of the workers, their work being so changed as to remove them from contact with the poison; education of the workers as regards the danger which threatens them, and the means of preventing it; research for and use of a less dangerous or harmless substitute, with the expectation that prohibition will be adopted.

In 1927 the manufacturers came to an agreement not to use white phosphorus in future.

Explosives factories produce and manipulate large quantities of nitric and sulphuric acids and of mixtures of the two. For this reason they ought to take the strictest precautions against toxic gases, and particularly against nitrous fumes.

Prophylactic measures which should be adopted against the fumes and
Among other safety measures, may be mentioned also those for factories where they make black powder and such explosives as nitroglycerine, picric acid, TNT, ammonal, and other munitions, drawn up by the German Trade Association of Explosives and Munitions Factories, and the pamphlets prepared by the Central Association of Explosives and Munitions Factories, dealing with such various products as smokeless powder, TNT, dynamite, nitroglycerine, nitroanisol, chlorated explosives, ammonal, and luminous signals used by the army, as well as depots for explosives and munitions.

Every country has laid down regulations for the manufacture and the use of explosives and black powder. They have also enacted measures for their storage and their use, especially their use in mines, quarries, and all kinds of underground workings. And, besides issuing detailed regulations on the subject of depots of explosives, whether in the open air, buried, or under cover, legislation has also been applied to depots of explosives over a certain size, e.g. containing 25 kg. of dynamite.

Every country, black powder, and firework factories are under the technical supervision of a competent central service. Such factories are only licensed on condition that they are at some distance from houses, built in one story, without roof-timber, with an iron frame-work, and of very light construction, so as to offer the least possible resistance to the explosion of the gases produced by an explosion. Each building must be separated and isolated by embankments or mounds of earth, one yard broad at the top and almost as high as the building itself. Lightning-conductors are needed, and the earthing must be carefully seen to. The floor of the workshops must be of beaten clay or asphalt, without gravel. Swing doors must be provided, opening outwards, two being provided for each building. Windows must be closed by glazed window-frames which should be made to turn in a vertical or horizontal axis. Natural lighting only must be used. Heating must be by hot water, or low-pressure steam; the heating apparatus must be isolated by a masonry wall; the pipes must also be kept from all accidental contact with inflammable or explosive substances.

Closed mechanical appliances should be installed, fitted with exhaust devices for the dust and fumes or poisonous gases, and, if necessary, with recovery plant for the solvents. Transmission gear of motors and machinery must be located outside. Every care must be taken to avoid sparks, any rise of the temperature either local or general, and any shocks or friction. The sun's rays must be excluded. The machinery must be supervised by skilled experts. Strict cleanliness must be enforced during every operation. All accumulation of dust must be avoided, or disposed of in any case, whether high up in the machinery or on the ground. The floor must be frequently sprayed with
water. As regards regulations for nitroglycerine factories, the reader is referred to the article on nitroglycerine. In chlorated-explosives factories, all accumulation of dry chlorates, as well as any impact or friction in the presence of wood, must be avoided.

There must be individual work-tables, separated from each other by partitions 40 or 50 cm. high, to prevent the spread of flame in case of fire or partial explosion. Only an amount of powder and products that is strictly required for one half-day’s work must be in use. The completed work must be carried, as soon as possible, to the magazine, which must itself be isolated, built of light materials, and entirely surrounded by earth embankments. Mixtures for coloured fire must be prepared gradually, according to the demand, and with absolutely dry salts.

The workmen must wear special boots without nails. Smoking must be strictly prohibited, or entry to a workshop or depot with a lamp, even if it is a safety lamp; no matches or steel or kindled or inflammable material may be taken into the workshops.

Fire-extinguishing apparatus and materials necessary for dealing with an outbreak of fire must be provided, such as water under pressure and sand.

No night work may be allowed under any circumstances whatever. In clear print at the entrances of the workshops must be posted regulations regarding safety and prohibiting smoking.

It is essential to have a medical service and first-aid organisation in explosive and powder factories.

Then again, in order successfully to combat occupational poisonings and diseases, there must be an adequate provision of cloakrooms and douche-baths, while special clothes and coverings for the head must be worn. Workers must undress, and then put on a special suit for work, and this suit must be drawn in as closely as possible at the neck, wrists, waist, and ankles. The head must be covered with a linen hood. The face and hands must be carefully and thoroughly cleaned with soap and hot water before meals. The men must be advised to keep their hair and moustaches as short as possible, and, as often as possible, to clean their nails, which also must be kept very short.

After work, they must undress to the skin, and take a douche-bath, and wash the hands and face as before. Special care must be taken when powder made with bichromate is handled (see that article), or if picric acid is handled, or when the workmen are exposed to nitrous fumes. For notification and compensation for occupational illnesses, see each special article.

In the Netherlands cases of mercurialism, observed among workmen in explosives factories, are compulsorily notifiable.

**BIBLIOGRAPHY**


*Cvrile Kraus*  
(Praque).
Factory Surgeons


The part played by a healthy, satisfied and stable personnel in modern industrial organisation is so important that no employer can afford to dispense with measures for trying to secure healthy conditions in his factory.

A great American industrialist has said that if it were possible to re-organise factory conditions afresh, the first service to be engaged would be the Medical Service. This idea is becoming more and more prominent, so that, even without legislative intervention, employers have created such services because, as the Americans say, they "pay".

The collaboration of doctors in industry has been statutorily imposed in several countries in industries where the persons employed are exposed to poisons or other occupational risks (glass works, explosive works, chemical works, work in compressed air, etc.). Legislation, then, aims at not only a preliminary examination of those applying for work, but also a periodic medical re-examination of workers, as well as organisation of first-aid equipment at the expense of the employer (first-aid boxes, ambulance room, medical assistance, etc.). (See article "First Aid ".)

"The value of medical service in industry was realised when compensation laws, which rendered it compulsory to provide medical and surgical treatment for injured workers, became effective. Medical and surgical preventive work (in America in particular) demonstrated that early attention to trivial accidents and injuries reduced the amount of time lost from work." (Dr. Ford.)

This illustrates how the social function of the doctor is not solely confined to unhealthy industries, and for this reason many large industrial establishments, even in the absence of legal compulsion, regard medical supervision as a necessity. The state of development reached in the United States, for example, by this service is shown in the statistics collected by the National Industrial Conference Board in 1925 (see table, p. 715).

The American Conference Board of Physicians in Industry has proposed the following formula as a definition of the position of the factory surgeon: "The physician in industry is one who applies the principles of modern medicine and surgery to the industrial worker, sick or well, supplementing the remedial agencies of medicine by the sound application of hygiene, sanitation and accident prevention; and who, in addition, has an adequate and cooperative appreciation of the social, economic and administrative problems and responsibilities of industry in its relation to society."

The characteristic, then, of the factory surgeon is his surplus of non-medical knowledge, of such a kind that he has a right to be considered as belonging to a distinct group of social servants. In fact he possesses, besides professional knowledge properly so called, competence enabling him to cooperate usefully in the progress of industry and in preserving it from the inherent waste due to accidents and illness.

The qualities of such a medical man, according to Dr. Ford, are as follows:

"He should be a man of good general education, possessed of honesty, tact, and judgment. He must have had a sound training in the fundamentals of his profession, a general hospital training of not less than two years, with special attention to general medicine and surgery. He should have had at least five years of general practice. The future industrial physician should maintain a connection with public health agencies, such as the city health department with its various dispensaries, the general dispensary and other public medical services, in order
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<td>1</td>
<td>20</td>
</tr>
<tr>
<td>Food and food products</td>
<td>9</td>
<td>4</td>
<td>11</td>
<td>7</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Hat manufacturing and fur dying</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
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<tr>
<td>Iron and steel</td>
<td>11</td>
<td>54</td>
<td>35</td>
<td>35</td>
<td>1</td>
<td>16</td>
<td>33</td>
</tr>
<tr>
<td>Leather and tanning metal trades:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Auto parts</td>
<td>18</td>
<td>4</td>
<td>8</td>
<td>24</td>
<td>-</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>(2) Brass, bronze and copper products</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>(3) Hardware, cutlery, jewellery</td>
<td>26</td>
<td>7</td>
<td>16</td>
<td>36</td>
<td>1</td>
<td>1</td>
<td>3</td>
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<tr>
<td>(4) Household and office supplies</td>
<td>11</td>
<td>6</td>
<td>5</td>
<td>16</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>(5) Machine and engine building</td>
<td>55</td>
<td>7</td>
<td>28</td>
<td>92</td>
<td>-</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>(6) Railway cars and railway products</td>
<td>13</td>
<td>9</td>
<td>6</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>(7) Wire and wire products</td>
<td>7</td>
<td>3</td>
<td>6</td>
<td>11</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(8) Miscellaneous, stamping, etc.</td>
<td>18</td>
<td>2</td>
<td>7</td>
<td>27</td>
<td>-</td>
<td>3</td>
<td>1</td>
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<td>14</td>
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<td>4</td>
<td>17</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
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<td>Paper and pulp</td>
<td>23</td>
<td>3</td>
<td>4</td>
<td>17</td>
<td>-</td>
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<td>1</td>
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<td>18</td>
<td>108</td>
<td>1</td>
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<td>1</td>
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<tr>
<td>Rubber manufacturing</td>
<td>31</td>
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<td>12</td>
<td>38</td>
<td>1</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Shipbuilding</td>
<td>13</td>
<td>1</td>
<td>1</td>
<td>8</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Shoes</td>
<td>10</td>
<td>4</td>
<td>10</td>
<td>9</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Smelting and refining</td>
<td>10</td>
<td>4</td>
<td>10</td>
<td>9</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Textiles</td>
<td>41</td>
<td>15</td>
<td>31</td>
<td>45</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tobacco manufactures</td>
<td>3</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wood working</td>
<td>15</td>
<td>1</td>
<td>5</td>
<td>27</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Totals</td>
<td>501</td>
<td>265</td>
<td>358</td>
<td>723</td>
<td>13</td>
<td>78</td>
<td>152</td>
</tr>
</tbody>
</table>
to develop the social viewpoint as well as to widen professional skill.

"The industrial physician should have a knowledge, not necessarily profound, of the fundamentals of industrial relations, including employment methods, labour turnover, job analysis, apprenticeship training, follow-up work among new employees, pensions, insurance, rest periods, absenteeism and general welfare problems.

"He should have a general knowledge of physical working conditions, accident prevention, disagreeable gases and dusts, heating, lighting, ventilation, locker rooms, toilets, wash rooms, rest rooms, restaurants, water supply, plant beautification, etc.

"A knowledge of housing conditions, transportation, general education facilities and other problems, together with the relation of the cost of living to local conditions, is essential. First-hand knowledge of the best methods of rehabilitating industrially handicapped workers is also a necessity, and the advice of the physician on questions of recreational and social activities is desirable.

In short the greater his knowledge of such secondary medical issues, the better qualified is he for his work of social welfare in the factory, and that is why the direction of the welfare department is often entrusted to medical men.

**Province**

Objection has been raised to the intervention of the medical man in the factory on the ground that it interferes with liberty at work, but this objection does not appear to be well founded. As a matter of fact, the work of the doctor does not at all interfere with individual liberty so long as the well-being of the individual himself or of the rest of the workers is not likely to be injured. The object of selecting workers and of their medical supervision is not to reject from the workrooms those who are mutilated and weak, but, on the contrary, to protect them against aggravation of their infirmities and to have them employed in such a way as to make use of their real occupational capacity.

But the doctor's activity depends, to a great extent, on the conception which the directors of the establishment have of the value of hygienic measures. Sand considers that a factory surgeon cannot very effectively carry out such a task unless he has supervision of about 700 to 800 workpeople.

At the start, the doctor is called upon to deal with the workman on his first engagement. At this first examination,
the manner in which he treats the workman — on the importance of which too much stress cannot be laid — sets up a personal contact from the start between the doctor and the future worker (see article "Vocation Guidance"). The doctor finds out the aptitude of each applicant, in order to ascertain possibilities of employment, inspired by the idea of the necessity of finding work for all.

Intervention arises on the following occasions: when a workman becomes the victim of an accident, when he returns to work after a prolonged absence due to a serious illness, or after short

Examining in September 1926 the question of rendering uniform the periodic medical examination in certain unhealthy industries, was of opinion that, failing official surgeons, surgeons chosen by some competent authority should carry out the duties, amongst whom the factory surgeons would be the first to be considered as answering the requirements. In this way the majority of industrial diseases of slow and insidious onset can be revealed in time and treated with advantage. On the other hand, periodic examination often reduces the difficulties of diagnosis, and especially it is so in the matter of prog-

![Diagram](image)

**Fig. 95.** — Course pursued by workmen suffering from a severe accident.

(Plates 83, 84 and 85 are from Oxford Loose-Leaf Medicine.)

and repeated absences due to slight indisposition, when productivity falls below standard, or even when, at the request of the manager or foreman, a workman is examined; finally, a periodic examination of the workpeople is of the first importance, because the medical man is able to diagnose the different maladies at an initial stage when treatment is most likely to be efficacious.

That is why the Correspondence Committee on Industrial Hygiene of the International Labour Office, when ex-

nosis, often so hazardous a task for the insurance doctor when faced with cases in which the symptoms are recurrent or latent. Without being called on to treat cases himself, the factory surgeon is indicated as the adviser so far as choice of a consultant or hospital is in question. Naturally, no interference with the liberty of the subject is concerned in the matter of his personal preferences, as the distinction between the duties of the factory surgeon and those of the treating physician are well understood.
The surgeon, further, should be able to evaluate the precautionary measures taken to protect the workers; supervision of the ambulance room, creche, hospital, sick benefit society and the like, in operation under the aegis of the factory where he is employed.

"As hygienist, he must devote attention to the following points: (a) General plant house-keeping, order and cleanliness. Cleanliness has a definite effect on workers. Dirty corners invite promiscuous spitting and other unwholesome practices. Dirt also holds moisture and favours the growth of bacteria; (b) Drinking water supply, particularly in regard to temperature and accessibility to workers; (c) Ventilation. An adequate supply of fresh air of proper temperature and humidity, with freedom from dust, and efficient exhaust systems where dust is a factor; (d) Illumination, natural and artificial; (e) Toilets, lockers, wash rooms, etc.; (f) Cuspidor service; (g) Proper drainage where wet processes are carried on; (h) Occupational health hazards; (i) In general, any condition unnatural to the physiological activities of the worker, especially posture and other fatigue-producing factors." (Dr. Sawyer, New York.)

Medical reports on cases should be inscribed on a card index system, under headings as to social position, precise occupation, past accidents, previous illnesses, etc. The doctor must keep the proctors in order and notify the industrial diseases and accidents in accordance with legal requirements.

Generally speaking, all factories of a certain size possess an ambulance room wherein the doctor carries out his examinations and any urgent treatment necessary.

The American Conference Board of Physicians in Industry, has drawn up a schedule laying down the minimum equipment for a first-aid room:

"A first-aid room should not be less than 9 x 12 ft. in size; should be well lighted and ventilated; should have running water, hot as well as cold, if possible; should be provided with toilet
facilities in or near the first-aid room. The light should be particularly good at the point where first-aid service is to be rendered, where an adjustable electric lamp would be very serviceable and convenient. Aside from ordinary good ventilation, it is desirable to arrange for a large inflow of air by fans or otherwise, to stimulate patients when feeling faint. The ceiling and walls should be light in colour and frequently cleansed.

"The room should contain the following minimum equipment: 1 metal combination dressing-table with drawers to hold instruments and dressings; 1 metal chair with head and arm rest; 1 metal stool built in combination with metal waste can; 1 small wooden or metal examination table with pads, with ends hinged to drop down; 1 stretcher, of the army type, or one of metal; 1 small instrument steriliser arranged for electric, gas, alcohol or kerosene burner; half-a-dozen utensils, such as arm and foot basins, quart basins, etc.; 1 portable iron and outfit; appropriate instruments, including razor, dressings, splints, drugs."

A first-aid station such as this can easily be installed even in small factories and allows the surgeon to render aid whenever circumstances require it. In larger works, this small station will be more or less increased by complementary accommodation; operating-room, laboratory, radiographic room, etc. A medical dispensary in a large American plant comprises generally a department for the examination of applicants for work and another for consultation and daily dressings.

The doctor can very often obtain the permanent collaboration of an oculist and gynaecologist (preferably a qualified woman whose duty it should be to conduct the medical examination of women workers) and sometimes a dentist and chiropodist. The statistics given above (p. 2) show the importance of works surgeon are to be found:

(1) those making it a whole-time service;
(2) those giving part-time service (a portion of every day or certain hours per week);
(3) those who only come into relation with the factory when called for consultation in case of sickness or for first-aid in the case of an accident.

The first type is found principally in large factories, the second sometimes in large works under the direction of a permanent medical officer. In small works, the third is the one generally met with, but sometimes the second is also encountered.

When a factory possesses no appointed surgeon, a nurse is very often engaged (see article "Welfare Workers"). For satisfactory working of the medical department, the ideal type is the full-time surgeon. While it is true that he is the representative and collaborator of the employer and that he is paid by him, it is obvious that the employer has the right to select him, although this fact ought not to imply absolute dependence of the doctor on his employer.

The latter must realise that complete liberty must be left to his colleague's professional conscience, for the factory surgeon can only do effective work for the general welfare provided that he is assured that he will not be subjected to material constraint when acting according to the dictates of his conscience. The functions of the factory surgeon will be the more usefully discharged the more fully the employer invests him with his confidence and lets him understand the inside working of his business and the processes of manufacture.

The Material Position of the Factory Surgeon

The factory surgeon is a collaborator with the management and, as an official in this capacity, must be differentiated from the physician who treats cases. His remuneration should be fixed like that of an engineer or works director, or be a definite salary with supplementary fees per visit and treatment. Generally speaking, three types of works surgeon are to be found:
It would nevertheless not appear possible for all the medical men in a dense industrial area to be thus treated in turn by the employer. Hence, a single medical practitioner, assisted by a deputy in case of illness and when on leave, should be appointed to the position of factory surgeon (Etienne Martin).

The overhead charge on industry for such an appointment is generously repaid. When the physician's duties are discharged intelligently, he becomes — as is well known — an asset rather than a charge on the industry. This is how a large number of American industrialists regard the matter.

Thus it has been calculated that two factories, employing about 20,000 workpeople with a corresponding staff, show a morbidity rate of 5 and 15 days respectively per worker per year according as they did or did not possess an adequate medical service, including initial and subsequent medical and sanitary supervision, etc. This difference in morbidity has its counterpart in the money lost by industry as the result of absenteeism from sickness. As a matter of fact, a factory with a medical department loses annually about $165,000 ($275,000 the cost of the sanitary service; $90,000 lost time from sickness), while one without any such service loses for absenteeism alone at least $437,500.

The following statistical data give information as to the sums devoted by American industrialists to the maintenance of factory medical services:

<table>
<thead>
<tr>
<th>Undertakings</th>
<th>Number of factories</th>
<th>Total number of employees</th>
<th>Fees paid to</th>
<th>External expenses</th>
<th>Cost of material</th>
<th>Total cost</th>
<th>Cost per head per employee</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Doctors and nurses</td>
<td>Assistants</td>
<td>$</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td>Less than 500 employees</td>
<td>81</td>
<td>24,557</td>
<td>126,928</td>
<td>9,800</td>
<td>32,191</td>
<td>14,981</td>
<td>$184,990</td>
</tr>
<tr>
<td>500-999</td>
<td>118</td>
<td>83,193</td>
<td>308,429</td>
<td>24,318</td>
<td>68,545</td>
<td>43,081</td>
<td>500,691</td>
</tr>
<tr>
<td>1,000-1,999</td>
<td>123</td>
<td>168,698</td>
<td>618,615</td>
<td>44,164</td>
<td>92,981</td>
<td>117,080</td>
<td>1,075,675</td>
</tr>
<tr>
<td>2,000-4,999</td>
<td>83</td>
<td>295,080</td>
<td>695,983</td>
<td>177,654</td>
<td>233,092</td>
<td>193,734</td>
<td>1,368,211</td>
</tr>
<tr>
<td>5,000-9,999</td>
<td>28</td>
<td>909,308</td>
<td>438,502</td>
<td>96,700</td>
<td>314,896</td>
<td>86,687</td>
<td>917,056</td>
</tr>
<tr>
<td>More than 10,000</td>
<td>14</td>
<td>209,070</td>
<td>701,701</td>
<td>74,778</td>
<td>310,608</td>
<td>169,881</td>
<td>1,283,713</td>
</tr>
<tr>
<td>Totals</td>
<td>447</td>
<td>1,031,279</td>
<td>3,077,639</td>
<td>446,760</td>
<td>984,223</td>
<td>556,247</td>
<td>5,306,132</td>
</tr>
</tbody>
</table>

The cost of the medical services of the factory in relation to salaries and production, according to an enquiry by the National Industrial Conference Board of New York (1924), is as follows:

<table>
<thead>
<tr>
<th>Undertakings</th>
<th>Number of factories</th>
<th>Cost of medical service</th>
<th>Per $1,000</th>
<th>Per $1,000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Conduction</td>
<td>salaries</td>
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<tr>
<td>Less than 500 empl.</td>
<td>20</td>
<td>0.78</td>
<td>4.18</td>
<td></td>
</tr>
<tr>
<td>500-999</td>
<td>38</td>
<td>1.15</td>
<td>4.14</td>
<td></td>
</tr>
<tr>
<td>1,000-1,999</td>
<td>40</td>
<td>1.09</td>
<td>4.40</td>
<td></td>
</tr>
<tr>
<td>2,000-4,999</td>
<td>20</td>
<td>1.00</td>
<td>4.56</td>
<td></td>
</tr>
<tr>
<td>5,000-9,999</td>
<td>6</td>
<td>0.83</td>
<td>2.30</td>
<td></td>
</tr>
<tr>
<td>More than 10,000</td>
<td>4</td>
<td>1.06</td>
<td>2.68</td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>128</td>
<td>1.02</td>
<td>3.60</td>
<td></td>
</tr>
</tbody>
</table>

The good results obtained have not failed to create an increasingly favourable opinion on the part of the employers as regards such services. At the tenth annual conference of the Industrial Physicians of the United States (4 April 1924) representatives of big business in America testified to the importance of the directors' contributing amply to the development of medical hygiene by demonstrating to the foreman the pride he should take in having his men in a dense working capacity, medical men are going to find the direct, the effective, the perfectly straightforward and legitimate path towards catching in advance those deteriorations of health, and the breaking down of the physical organisation, which it is their major duty to perform for us. (Howell Cheney, Cheney Bros., South Manchester, Conn.)

"Industry, it is said, expects, and has a right to expect, that in allaying those little, trivial ills that so affect the immediate working capacity of employees, medical men are going to find the direct, and in the actual working service. At the tenth annual conference of the Industrial Physicians of the United States (April 1924) representatives of big business in America testified to the importance of the directors' contributing amply to the development of medical hygiene by demonstrating to the foreman the pride he should take in having fit workmen under his orders. Employers, it has been said, should collaborate with industrial physicians and it should be the duty of the employer to make a special study of the prevention of accidents. In this matter much progress could be achieved by more patient study if recourse were had in a more methodical fashion to the advice of medical experts. (C. R. Hook, American Rolling Mill Company, Ohio.)

"Industry, it is said, expects, and has a right to expect, that in allaying those little, trivial ills that so affect the immediate working capacity of employees, medical men are going to find the direct, the effective, the perfectly straightforward and legitimate path towards catching in advance those deteriorations of health, and the breaking down of the physical organisation, which it is their major duty to perform for us. (Howell Cheney, Cheney Bros., South Manchester, Conn.)

"The physician in industry has amply justified this trust and responsibility placed in him by the employers, and has proved himself a
necessary and integral part of an industrial organisation employing a considerable number of men and women. " (Magnus W. Alexander, National Conference Board.)

In some cases the attention which the factory management pays to the health of the workpeople does not limit itself strictly to these, but sometimes embraces also the members of their families. This is the case notably of a large tannery and boot factory (Endicott-Johnson Corporation), which employs 15,000 workpeople in Endicott, Johnson City and Binghampton (N.Y.). For a dozen years this business has instituted a complete service, taking the view that "the family is a biological and economic unit, depending for its existence on the salary of the individual and profoundly influencing the output." (D. C. O'Neil). In reckoning for each workman three members of his family, the medical attendance covers 60,000 persons. No direct charge falls on the workman and the increase in individual production and the profits which result to the undertaking cover the expense entailed. For the year 1927, the cost of the medical service amounted to $789,000, which comes to $52.60 per head. The undertaking, however, makes the consumer pay these expenses and for the year in question the sum charged on the 32 million pairs of boots turned out only amounted to 2.50 cents per pair.

**Instruction and Professional Education of the Factory Surgeon**

In order to become a factory surgeon, a man must acquire, once he has qualified, theoretical and technical knowledge which is indispensable; knowledge of social legislation relative to accidents and industrial diseases and to victims of the war or of industrial accidents employed in the factory; the laws on public health and especially the Factory Act. It is indispensable also that he should have practical knowledge of medico-legal examination of the injured and the drawing-up of certificates and reports, and, on the other hand, a good knowledge of modern industrial installation, so that he can compare and understand those which come under his purview. Finally, he ought to have sufficiently precise knowledge of industrial toxicology. (Etienne Martin.)

According to Papanti-Pelletier, the factory surgeon should have a profound knowledge of industrial traumatic surgery, radiology and physical methods of treatment, as well as of vocational guidance. He insists most particularly on the fact that the factory surgeon should not only be a good physician but also a good surgeon, the branch of industrial medicine concerned with accidents consisting to an extent of four-fifths in surgical and clinical pathology.

The Conference of Industrial Physicians of the Eastern States (New England) has grouped, in the form of a table, the matters which seem to be indispensable in the instruction of the factory surgeon. This programme is certainly not final, but may be looked on as a starting point when worked out in any future plan:

*First Group.* Special professional knowledge, technique as to medical examinations at the factory, first-aid in case of accident, occupational risks to the health of the workman, professional
re-educa,+on, analysis of the processes, lighting and ventilation, medical deontolagy applied to industry.

Second Group. Organisation and manner of functioning of the medical industrial service, industrial dispensary, organisation equipment and technique, industrial medical posters, nursing service, establishment of budgets and administrative work.

Third Group. The objects of industry and its relation to society, objects of industry and its place in society, theory and practical application of insurance laws, Workmen's Compensation Acts, factory organisation, methods of training workers, sanitary laws applied to industry.

The problems of the professional training of the factory surgeon has not yet been solved; the universities, except very occasionally, provide no special instruction. However, there is no necessity to create new chairs to fulfil this object, because it would be sufficient to adapt a certain number of existing courses to embrace this aspect. These are courses on clinical medicine and surgery, forensic medicine and hygiene, which are all included in the syllabus, and it would suffice to develop the teaching of industrial toxicology and the study of occupational diseases and to do so not only by lectures but also especially by practical demonstrations.

Most countries possess a staff of technical inspectors and often also medical inspectors of factories. It would not be difficult, therefore, to bring about collaboration with this staff and to obtain permission from occupiers to allow visits to be paid to factories for such of their students as might hope to become factory physicians. Occupiers and civil servants would not refuse to co-operate with such a useful object in view. (Etienne Martin.)

In conclusion, for the establishment of a successful medical service in a factory, the following conditions ought to be complied with (Dr. Sawyer): sympathetic co-operation of the directors, competent and suitable personnel, an installation suitable to the needs of the establishment and a programme showing proof of almost day-to-day progress together with maintenance of a high standard.

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Prof. Etienne Martin (Lyons).

Fatty Substances


This article deals with oils and fats of animal and vegetable origin. The article "Petroleum" deals with mineral oils or lubricating oils.

Animal and vegetable oils and fats are often included under the denomination of "fixed fatty bodies", that is, substances which, when subjected to a sufficiently high temperature, do not evaporate in their original state, but become decomposed. Most of the fixed oils rapidly become oxidised when heated. For this reason they are not used as lubricants.

(a) The vegetable oils most used in industry as lubricants are:

Colza oil, which is at the present time used for oiling machine-tools, either pure or in a mixture. Its neutrality has always to be verified, as it is purified with sulphuric acid. Similar oils which, however, are not so good as lubricants are: ravison (Black Sea rapeseed); copra
or coco (olein); arachide (peanut oil), very little used; cottonseed oil, used as a sprinkling lubricant for metal work; linseed, unsuitable for lubricating on account of its drying properties, which, on the other hand, account for its being used in paint preparations; olive oil, certain qualities of which are used in the preparation of wool; oil from the palm and cabbage palm, useful in the preparation of certain hard industrial fats; castor oil, used to lubricate the motors of aeroplanes, and for greasing rubber fittings. Insufflated or thickened oils are oxidised by blowing compressed air into the midst of a heated liquid mass of colza, cotton and sometimes castor oil; they constitute soluble sprinkling oils, or raw oil for locomotives and marine machinery. Resin oil, which is chiefly made up of hydrocarbons and not of glycerine, like the other vegetable oils, is used in the preparation of very cheap products.

Oil from kernels: see article "Ethylene" under Uses.

(b) Animal oils, alone or mixed with vegetable or mineral oils, are used for lubricating machine-tools.

Among these the oils should be noted tallow, used at the present time in a mixture to lubricate steam cylinders, and lard. If lard is of the best quality and not rancid, the oil is cheap and good for all kinds of work. The best quality is that which has the lowest percentage of fatty acids. When mixed with mineral oil, it is used more than any other oil for lubricating machine-tools, and in the textile industry; neat's-foot oil is used less and less, on account of its coarseness, for lubricating delicate machinery, for making lace and in the hosiery trade; spermaceti oil is one of the most fluid oils, but expensive. It is mixed with mineral oil to lubricate some light kinds of high-speed machinery; it is composed of alcohols and ethers. There are besides fish oils from seals, whales, sharks, dolphins and porpoises. These mixtures are used for lubricating marine machinery and for oiling clock work. There must not be omitted mention of fats from leather or skins, recovered from waste from tanneries or leather works by means of petrol, or by heating with acidulated water, the strong smell being weakened by the addition of nitrobenzene; fat from glue; fat from waste water, from fulling or from kitchen garbage and fats: from residues from wool (this must not be confused with lanoline), extracted from the wool residues in factories with carbon bisulphide and other solvents.

**Technical Data**

(A) The oil from oleaginous seeds may be extracted: (1) by direct pressure, by means of mechanical or hydraulic presses; (2) by extraction by means of volatile solvents.

(1) The mechanical press has been known from the most remote times, and up to 1795 had only received very slight alterations; that was the date of the invention of the hydraulic press. This is used in the form of the press called the "marseillaise", or the Anglo-American or framed type. The first is very practical, but requires too much hand labour and consumes too many press bags. The Anglo-American type, which uses cloths or matting, is regarded as a press for the second pressing.

At the present time continuous working automatic presses form the basis of the processes for extraction by solvents. The continuous press includes: (a) an automatic distributor for the seeds to be passed through; (b) a heater, which is composed of a double jacket for the circulation of steam, and, if required, an arrangement for humidifying when the seeds are too dry; (c) the press itself. This type does away with all hand labour; simple supervision is sufficient.

(2) Extraction by volatile solvents, preferably by bisulphide of carbon, is used only for materials poor in oil, or for special products such as the husks of olives, and oily rags. About the year 1890 other solvents, such as petrol and benzine, were tried; but it was difficult to eliminate completely all traces of foreign matter introduced by the solvents. At the present time the chlorated compounds of ethylene (trichloroethylene, etc.) are much used. Some complicated apparatus turns out the oils and oil cake for animal food, and treats the seeds without preliminary pressure. But it is preferable to begin with pressing, and to finish with extraction by means of solvents.

Extraction by solvents is carried out either in a fixed apparatus, which may be vertical or horizontal, in which the solvent circulates through the material to be extracted, or in horizontal rotary apparatus, in which the material is shaken up with the solvent. These various apparatus may or may not be fitted with mechanical stirrers. They include, generally, a cylindrical extractor, an evaporator, a condenser, a container for the solvent, a water separator and an arrangement for the recovery of the solvent. Diffusion is often carried out by heating; an injection of steam follows the separation of the oil from the solvent brought about by heat. In the recuperator, the solvent, caught by the incondensible gases, is retained by mixing with an absorbent oil. In some types, even the
drying of the material to be treated is carried out in the extractor. The technique also makes use of chloride of ethyl, with the double object of obtaining extraction and refrigeration.

The oils obtained by the preceding operations always contain a certain quantity of organic material: mucilages, albumens, waxes, resins and water which have to be removed if a good commercial product is to be obtained. Refining operations include a preliminary decantation at 60-80°C, or a filtration — often both in succession. In the extraction system by solvents, filtration of the oil-solvent mixture can be sandwiched between the extractor and the distillator. Then follows neutralisation, bleaching and deodorisation.

Neutralisation, which more or less eliminates completely the free fatty acids, is carried out by means of lye or caustic soda. The decanted oil is then subjected to several washings with warm water and dried in a vacuum. The oil, partly decolorised by neutralisation, is completely decolorised by means of such decolorising earths as fuller’s earth and silica gel, which are stirred in and heated with the oil. They are separated in a filter press. The impure oils and the various wastes from refining are bleached by means of hydrogen peroxide; in the old days animal charcoal was used. Sulphurous anhydride, powdered magnesia in the presence of water, ozone and potassium permanganate are also used.

Fats in the early stages may only be necessary for second quality oils; but deodorisation is required for almost all oils. It is almost always done by using very pure steam. When metallic materials in colloidal suspension have to be eliminated, methods of catalytic hydrogenation are often introduced; the treatments with sulphuric acid, with chromic acid mixtures, and with kaolin are not sufficient, and recourse must be had to the action of organic acids, such as oxalic, lactic, citric, or their salts.

(B) Non-edible fish and fish offal are used for the extraction of fatty material and after that for preparing food for cattle or a manure to be applied either directly, or in the form of composts mixed in alternating layers with earth. Treatment is carried out by a physical process with water or steam, or by a chemical process. In the first, the fish is boiled with water or in autoclaves which prevent all escape of offensive smells. The residue is then pressed and dried. The liquor from the boiling, when concentrated, gives glue.

In the second, volatile solvents, mentioned above, are used, which in up-to-date methods are made to act on the materials previously dried. Sometimes offal is also dissolved by means of strong acids, either hydrochloric or sulphuric. The liquor with the offal in solution is mixed with such absorbents as peat and phosphates, and used as manure.

Fish containing less fat are simply dried or dissolved after an acid bath. An industry for solidifying oils by hydrogen makes use of the refuse or the excess of some oils which are little used by themselves, by transforming them into solid fats.

Uses

Vegetable and animal oils are used in industry as lubricants, especially when mixed with mineral oils (see article "Petroleum"). They cannot be recommended for lubrication in the pure state, because the increase of temperature of the machine-tools considerably reduces their viscosity.

On the other hand, drying oils are used in the preparation of varnishes and paints. Semi-drying oils can be used as lubricants when mixed with mineral oils. Rags or waste material impregnated with drying oils constitute a danger in works, for the oxidation of the oil may raise the temperature to the point of causing spontaneous combustion.

"Batschöl" is a mixture of vegetable or animal oil, mineral oil, water and soap; it is used in the weaving of jute.

The oils and fats used in soap works are dealt with in articles "Soap Industry" and "Candles". In margarine factories where such dilute mineral acids as sulphuric are used, during the preparation and melting several acids are given off, like stearic and palmitic acids, which have no effect on the system, whereas such other products as acrolein are extremely irritating and caustic (see article "Acrolein").

Fish oils are used for currying hides; an inferior quality is used in soap works and in chamois-leather factories. Fish oil, especially from tunny fish, is used as fuel in semi-Diesel motors.

Sources of Dangers

Animal fats rapidly putrefy, which makes the handling of them very unpleasant; the process is due to decomposition of albuminoid materials into pyridine and homologues, with the emanation of offensive smells, which may nauseate the workers and the
inhabitants of the vicinity. This smell, which strongly impregnates the workers' clothing and is so offensive that it sometimes injures their health, is noticed especially where suet is evaporated to dryness; even melting with steam is not inoffensive. The odour is only to be avoided by melting in vacuo.

Some sources of injury are due to the various substances used, and especially to the solvents (see articles "Solvents" and "Ethylene" under Uses): petrol, carbon disulphide, benzol and its homologues, tetrachloride of carbon and trichlorethylene, all of which exercise an injurious effect on the central nervous system, and, by their defatting action on the skin, may set up dermatitis. Risk of fire and explosion must also be borne in mind. The use of chromates, of compounds of lead or manganese, and of mineral acids should not be overlooked when causes of injury are being enumerated.

Pathology

As a rule, animal and pure vegetable oils have no injurious effect on the skin; and, if cases of dermatitis are found, it must be admitted that there is a particular individual sensitiveness, or that it is due to the effect of other substances present in the oils. If the skin is intact, such lesions are exceptional. The oils are generally sterile and antiseptic, and only contain pathogenic agents in a mechanical way by superficial adhesion.

Hence the number of cases of injury due to the oils in question is very restricted. Lewin has reported some cases of eczema from poppy oil; E.G. Graham, from olive oil in an infant; Collis, among women working in English tobacco factories (here the eczema was situated on the back of the left hand and forearm, and was due to the olive oil, used in rolling plug tobacco leaves, degreasing the skin); Guhrauer, in some women using substitutes for rapeseed oil when working on gold chains; Oppenheim, among workmen using linseed oil in putty; Casazza, in cheese makers, from the same oil, used for the preparation of the crust on the cheeses; McConnell, Blaschko and others from the use of colours and paints with a basis of linseed oil (but here the effect of other substances present, such as turpentine and alcohols, should not be forgotten); a case of eczema was reported in 1913 by the Dutch Medical Inspection Department in an oil works. Coco fat has caused erythema and eczema localised on the arms;

"Kunerol", according to Oppenheim, has been the cause of impetigo on the back of the hand. Dermatitis has been once observed from wool fat and other cases from animal fats; fish oils (Fischer: with a general prurigenous form); margarine and suet (according to Grun: characterised by an eczema situated on the abdomen, account of carrying the fats in tubs, resting against the abdomen; in this case some red patches, vesicles and even erosions were found).

The cases of erysipelas mentioned by Grun had little tendency to heal and were accompanied by lymphadenitis and lymphangitis. However, most workers did not show any ill-effects, so that experts consider a special sensitiveness of the persons affected must be recognised. Some cases of pyodermatitis, definitely caused by contact with affected workers, have also occurred.

Mixtures, frequently used in industrial practice, of vegetable or animal oils and minerals oils very often cause dermatitis in the workers who handle them. In these cases it is difficult to decide the part played by the various elements of the mixture. Dermatitis from the mixtures of olive oil and lard has been observed, also from mixtures with a glycerine base and Turkish red oil, which is only oleic acid, a secondary product in the manufacture of soap — Haily and William Howard report the case of a typist using a product made up of this composition.

In addition to the cutaneous forms described, eczemas around the nails have been noticed in workers who cut up fat before melting. This is due to chemical and mechanical action, and is accompanied by a very pronounced effect on the conjunctival mucous membrane of the eyelids and cornea, due to the vapours given off.

It should be noted that, in the cases mentioned, the persons had a marked skin reaction to tests (according to Block) and even a general reaction, with headaches, fever and a feeling of weakness.

Cases of poisoning by acrolein (see that article) are not common. Cases have been reported in Great Britain (1910), Holland and Bavaria (1912). In 1928, Koelsch described two cases of acute fatal poisoning from acrolein, which occurred during autogenous soldering work in a boiler which had contained rapeseed oil. The oily layer adhering to the sides, under the effect of high temperature, rising to over 300° C., became decomposed, giving off acrolein fumes. The effect of these fumes was all the more serious as they were given off in a confined space.
Fuller details of the pathology caused by fatty oils are given in articles "Petroleum" and "Skin Diseases".

HYGIENE

All operations affecting vegetable oils, fats and animal oils require almost the same hygienic measures; they should however, be stricter for the treatments of fats and oils of animal origin.

Thus, for example, works which deal with fish oils and animal fats must be erected at a distance from dwellings.

The construction of oil works must be of fireproof materials, or, where that is impossible, the exposed wooden parts must be given a coat of plaster or of impermeable and washable varnish.

The floor, both in the workshops and yards, must be made impermeable. There must be thorough ventilation of the workplaces; and openings on to the public road and neighbouring properties must be kept closed.

Such raw materials as animal fat and fish should be conveyed in closed watertight receptacles. They must be treated as soon as possible after their arrival at the factory.

Covers must be placed on the vats, whether heated by steam or hot air; fish and fat should never be placed on the open fire. All gases and vapours must be led into the chimney or under the furnace bars (taking, in this case, necessary precautions).

Grinding mills and presses must be placed far from dividing walls, to prevent causing annoyance to neighbours by the noise.

The treated raw materials must be placed in a dry place and covered with a layer of lime or animal charcoal, which must be removed two or three times a week when fish offal and bone waste is being treated.

If necessary, the waste water must be decanted and turned into a sewer or carried some distance to the open country in closed watertight receptacles.

Cleanliness of workplaces is important; frequent washing down is required with water treated with chlorine or formalin.

Purification of the oils should be done as far as possible in the cold state. Residue from the purification must be deposited in metal tanks, placed far from the workshops.

Every necessary measure against risk of poisoning, fire and explosion, from carbon disulphide, petrol, benzois, or trichlorethylene, must be taken in the factories or during the operations which require the use of solvents capable of giving off poisonous or explosive fumes.

As liquid, whether oil or other material, may chance to be upset, the floor should be constructed so that it slopes down to the middle to form a basin, to prevent the liquid from flowing outside.

The recovery plant must be fitted with every possible device for limiting or excluding danger of poisoning, explosion or fire. If necessary, this apparatus must be placed under an exhaust ventilator.

Workers must be instructed in regard to the dangers to which they may be exposed. Personal protection must be adopted, especially for the skin, and also measures of individual hygiene. If necessary, periodical medical examinations must be instituted.

LEGISLATION

In Belgium, work is prohibited for young persons under sixteen years in neat's-foot oil works, where smells from putting animal matter are given off; in works where reddish-brown oil is extracted from the residuum of melted tallow and from debris of fat at high temperature; and in the preparation on a large scale of linseed oil. Boys under sixteen years and women under twenty-one years are excluded from the extraction of oil by means of carbon disulphide, when poisonous fumes are given off. In France, young persons under eighteen years, and women also, are excluded from the treatment of cake of crushed olives by carbon disulphide. In Italy, boys under fifteen years and women under twenty-one years are excluded from the extraction of oils from olives and other oils or fats by carbon disulphide.

In Great Britain an Order of 5 July 1929 (No. 534) deals with measures for the welfare of workers employed on oil cake.

As regards legislation see also articles "Solvents", "Petroleum", etc.

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Fatigue in Industry

Fatigue is generally defined as the diminished capacity for work which results from prolonged activity (Kent, Spaeth). It may be local, partial or general; it may be threatened or manifest, slight or severe. The pure physiologist is concerned mainly with general; interconnection are profoundly modified by the manifold conditions. Systems, under abstract experimental (Spaeth).

Thus the products of activity of one region, tissue, or organ may in the intact organism diffuse through the circulation of the blood so as to affect the capacity for work of other regions, tissues or organs. Or the exercise of one region, tissue, or organ may, by its nervous connections, affect the simultaneous activities of other regions, tissues or organs, especially the activities of various levels of the central nervous system, which may in turn determine the activity of any other region, tissue or organ. As an example of the latter complicating influences may be cited the temporary performance of increased muscular work (thus defying the ordinary definition of fatigue) as the result of muscular or other fatigue (Rivers).

This condition arises, in part, from changes in higher levels of the central nervous system, temporarily releasing the usually restrained activities of lower centres and thus enabling the organism to draw on reserves of energy which are normally "inhibited".

In the intact organism, fatigue is manifest not merely by a loss of functional power; it is also accompanied by a characteristic "feeling" of weariness and of lessened capacity for further work. This feeling is dependent both on peripheral and on central (nervous) conditions. The changes occurring during sufficiently prolonged industrial work may give rise to a feeling of "boredom", which is subjectively indistinguishable from that of "fatigue". In everyday life there is a fairly close relation between this feeling and the performance of work (Muscio). But when the task is of short duration, as in certain laboratory experiments, the feeling is no criterion of the work that can be performed (Dhers).

Finally, as has been proved by laboratory experiments, the capacity for work, both mental and muscular, is affected by interest, suggestion and other higher psychical factors, which may mask, inhibit, or otherwise delay the onset of fatigue or boredom (Wright).

The physiologist has studied fatigue in three systems: the muscular, the peripheral nervous, and the central nervous systems.

Fatigue in the central nervous system, as mechanically conceived on the basis of the study of isolated muscle, appears to be safeguarded by "the interplay of opposed agents" (Sherrington), those of excitation and inhibition, each of which must be regarded as a relatively separate, active process and presumably as separately amenable to fatigue.

In regard to the peripheral nerves, physiologists have shown that they are virtually indefatigable. The peripheral nervous impulse appears to be of a physical rather than of a chemical nature. The activity of nerve fibres manifests itself as a rapid series of impulses, each of which is momentarily followed by a refractory period, a period of recovery — during which a fresh impulse cannot be developed. But such perpetual blocking and unblocking is probably incomparable with fatigue.

Less ignorance exists on the subject of muscular fatigue, but even here physiology has only been able to throw a very uncertain light on the subject. It is known that when a muscle contracts lactic acid is formed; we suspect that lactic acid may be the cause of the contraction of muscle and of its ultimate fatigue. And there can be no doubt that the lactic acid produced when muscle is stimulated arises from the breaking down of pre-formed glycogen. Oxygen is used solely in the process of recovery, i.e. in removing the lactic acid. The greater the degree of lactic acid concentration which an individual's muscles can tolerate, and the greater his intake of oxygen which can remove the lactic acid, the longer he will be able to resist fatigue (Hill).

Sooner or later, the lactic acid cannot be removed from the exercised muscles as fast as it is formed. It then diffuses into the blood, and this may be one cause of the ensuing fatigue. Resting muscles may assist active muscles in dealing with the lactic acid produced by the latter. But ultimately the increasing intake of oxygen by the lungs reaches a limit which cannot be exceeded. At the highest speed of running, for example, the oxygen required to deal with the lactic acid formed is enormous, and the onset of
Fatigue thus becomes inevitable (see article "Industrial Physiology").

So far muscular fatigue has been referred to as if it were due solely to the changes occurring in muscle. But the complexity of muscular excitation in the intact organism is well shown by the ergographic record which reveals, in the form of an ergogram, the extent and number of flexions and extensions of a single, isolated joint in the intact organism.

That the ergogram is not a simple record either of insufficient available glycogen or of excessive accumulation of lactic acid is shown by the following considerations. When the subject has reached the stage when he is quite impotent to produce further movement of his finger, he will immediately be able to furnish a good ergogram if the weight which his finger is lifting is slightly reduced. From another aspect, too, the stage of absolute exhaustion which he has reached is only apparent, so far as his muscle is concerned. It will still readily contract if the stimulus of an electric current be applied to his arm over the appropriate peripheral motor nerve. The so-called fatigue effects revealed by the ergograph are very largely of nervous origin, due to afferent impulses ascending from the tiring muscle and inhibiting the transmission of afferent impulses which would otherwise throw it into action. They are protective against truly muscular exhaustion, and the relation between such nervous inhibition and the degree of truly muscular fatigue occurring is not known. It is known that under conditions of severe general fatigue such inhibition may fail, and thus a better ergographic tracing — i.e. a larger amount of work — may be compatible with increased fatigue.

Turning now from the muscular fatigue produced in the laboratory to the muscular fatigue of industrial work, we are at once confronted with the fact that the conditions under which the industrial worker carries out his daily work are very different from those under which an ergographic record is taken. The worker does not confine himself to the use of a single muscle. By varying his posture, as he tires, he often brings other muscles into play to carry out the same operations as heretofore. He does not work his hardest at each muscular contraction, as the ergograph demands of its subject. More or less unconsciously, he adapts his expenditure of work to the length of his unbroken working spell or working day.

The fatigue which such a worker suffers is not merely or principally a fatigue of effort; it is also largely a fatigue of skill. There is no industrial work that is, strictly speaking, unskilled. For there is no occupation in industry in which there are not good and bad methods of carrying it out. The best worker is he who has become expert in the most efficient methods. He shows less fatigue and less liability to accident than the less expert worker (Farmer, Loveday and Munro). Co-ordination, integration, and inhibition are thus the essential nervous processes both for securing the minimal expenditure of muscular effort and for yielding the maximal efficiency of output. As skill is acquired, the field of consciousness becomes reduced both in extent and in intensity. The need for widely diffused attention and for continuous judgment becomes replaced by the establishment and maintenance of an appropriate conscious "attitude" in which the work is carried out, to a large extent, automatically. But when fatigue arises, the discarded conscious attention to details is revived. Voluntary effort replaces unconscious behaviour — but with much less success. Output is reduced not only in quantity, but also in quality. The expert worker falls to the level of the inexpert worker. Extravagant energy is expended (Farmer and Brooke). Old faults reappear, accidents increase, and, finally, disorder replaces order of movement.

Moreover, apart from the fatigue of muscular contraction, there is a fatigue of the posture of the muscles employed, a fatigue of the central nervous "set" which is responsible for the preservation of the favourable posture — a fatigue, it may well be, of the directive process established.

Lastly, not only are the various simultaneous movements integrated together by practice so as to form a single whole, not only is there this integration of a spatial kind, but practice also brings about an integration of a temporal kind. Successive movements are integrated together, and here the influence of rhythmical performance is of the greatest aid. The value of acquiring a proper rhythm in repeated movements can hardly be exaggerated. This kind of integration likewise breaks down in fatigue.

Impotence to express these changes in mechanical terms renders it necessary to measure industrial fatigue by its more immediate effects. Numerous attempts have been made to introduce specific tests of fatigue, but at the present time they are all in varying degrees unreliable (see article "Fatigue Test"). Its effects can only be safely...
studied by recourse, not to the interpolation of so-called fatigue tests, but to the actual industrial work curve. It is necessary to measure output hour by hour throughout the working day, and to study how the output rises and falls both in quality and in quantity at different hours of the day, on different days of the week (Loveday and Munro), with different lengths of the working day (Goldmark), and so on, and by what length of rest it is restored to its original level. Both curves of total output and curves of spoilt work for different kinds of work are studied. Attempt is made to introduce improvements in environment — illumination, ventilation, temperature, clothing, etc. — improvements in arrangement of the worker’s material; improvements and periodic changes in the worker’s posture, in the number, nature, and rhythm of movements, and in material design; the introduction of rest pauses in a long, previously uninterrupted spell of work, and a better selection of the worker according to his innate abilities and interests. There are studied separately the effects of these changes, one by one, both on the height and on the form of the work curve (Farnier).

It is known that when the worker starts his work he has to “get into his stride”, to “warm up” to his work, to overcome distraction, to settle down to a rhythmic method of working. It is known that when he resumes work after a pause, he also suffers at first from having to overcome such detrimental effects. But the psychologist does not confuse these effects with loss of practice. A few minutes’ absence from work does not produce loss of skill; any more than does a few minutes’ pause between the repetitions of a well-learnt poem produce a loss of memory. What is lost in a short rest pause is not loss of practice but loss of what the psychologist calls incitement and settlement (Krapelin).

During a rest pause, moreover, the effects of fatigue disappear, and in general the beneficial effects of a rest pause so far outweigh the detrimental ones that an increase in output results despite the somewhat lessened period of time actually spent at work. Increases varying between 5 and 13 per cent of the output have been recorded in numerous investigations (Wyatt).

The good effects of a rest pause — as, indeed, the good effects of reducing the total number of hours worked — may not be fully evident until several weeks or even months have elapsed (Vernon, Bedford and Wyatt). The worker needs time to become adapted to the more advantageous conditions of his work. Ideally, each worker needs a different length of rest pause and a different moment for its introduction in order to produce its best effects. In practice, however, the workshop, like the school class, has to adopt procedures which are most advantageous to the majority of its members.

The work curve is likewise complicated by the presence of spurs — one of which is specially apt to occur when the end of a piece of work, or the end of a spell of work, or the approach of payment is in sight. Besides the end spurt there may also be an initial spur, when the worker comes fresh to his task with a degree of energy which soon falls off after the first few minutes. The work curve is also marked by spurts and falls at other periods, due to various mental and physical influences.

Of these mental factors the most important are of affective nature. The worker’s feelings alter at his work. The feelings are of enormous importance in influencing mental and muscular work. On the one hand, they may conflict with the general attitude he has to maintain and the efforts which consciously or unconsciously he has to expend; or, on the other hand, they may assist in those directions. Irritation and boredom are obvious examples of the former; contentment and interest of the latter.

Just as efficient muscular work demands the maintenance of a favourable posture (Bedale and Vernon, Kunze and Schulkof), so efficient mental work demands the maintenance of a favourable attitude. This attitude is, of course, maintained more easily in states of contentment and interest, less readily in states of resentment and boredom. So long as the worker is happy and interested, the favourable attitude can be preserved without effort; its preservation involves the successful inhibition of all antagonistic, incompatible attitudes. Such inhibition is apt to tire when interest fails. Discordant ideas or movements are no longer automatically suppressed. They become manifest and themselves inhibit industrial work. Conscious voluntary effort has to be invoked in order that the mental or motor task may be continued. As this wears, boredom is felt and the need for a change of attitude becomes imperative (Miles and Skilbeek).

It is now realised how far the boredom arising from an ungenial task may be safeguarded by a more careful selection of workers. Too intelligent a worker for the kind of repetitive work
in which he is engaged may be as unsuitable as a worker who has not sufficient intelligence for another job (Burnott, Wyatt and Fraser). The work must be adapted not only to the level of general intelligence, but also to the special abilities of the worker. As a general rule, the dull worker prefers a more monotonous job. He does not want changes. He safeguards himself against boredom by recourse to the phantasies of day-dreaming, to conversation, song, etc.

At the outset there might have been a tendency to define industrial fatigue as that result of previous industrial work which is manifested as a diminution in output. But, as has been shown, fatigue may temporarily result in an increased amount of work due to the tiring of higher-level inhibition and control, and may result from many other causes than that of previous industrial work. The worker may for quite other reasons come to his work in a fatigued state. His lack of training, his use of needless movements, his whole mental and physical environment may be the true causes of his fatigued condition rather than the number of hours which he has already worked.

Further, diminution of output as the work continues may result not only from fatigue, but also from lack of incentive or from boredom, resentment, irritation and worry — causes which if prolonged and resisted will ultimately cause fatigue, but the removal of which in their early stages of occurrence will at once produce a rise of output. Their adverse influence on output is initially due to temporary inhibition. How is industrial fatigue to be distinguished from inhibition? Only by observing the effects of removing their respective causes. If the reduction of output at once disappears, its causes may justly be attributed to previous inhibition. If the reduction of output is gradual, its cause may (with less certainty) be attributed to previous fatigue.

In the majority of cases, under present-day conditions, industrial fatigue is not to be reduced by shortening the hours of the day's work. It is to be combated rather by the avoidance of too long uninterrupted spells of work; by the abolition of overtime and before-breakfast work, so far as is possible; by the introduction (after careful study of the work curve) of rest pauses, and of change of work and posture; by determination of the best movements of the worker; by systematic training of the worker in those movements; by selection of the worker so that his occupation is adapted to his innate abilities; by the abolition of causes of needless resentment, irritation, and worry; by the introduction of suitable incentives to work; by the provision of a good physical environment in regard to illumination, temperature, humidity, ventilation, food, etc. (Dürig, Myers, Riedel).

As has been seen, industrial fatigue is too complex, and knowledge of the physiology of the nervous and muscular systems is too rudimentary, to allow of a definition of its character in physical and chemical terms. Indeed, it may be of a nature that forbids complete definition in the language of pure mechan-ism. At present it can only be studied and estimated by means of industrial work curves — curves of output and curves of spoil work, indicating variations in the quantity and the quality of the worker's products. It must never be forgotten that industrial fatigue involves not merely a diminution in the quantity of the worker's available "energy", but also a lack of harmony, a disorder of the various nervous processes which determine his performance of mental or bodily work.

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Fatigue Tests


Fatigue tests comprise the different methods of measuring industrial fatigue. The evaluation of the latter is concerned with three distinct matters
for consideration in the scientific organisation of work: determination of the suitability of the work to the psycho-physiological constitution of the individual; determination of the more or less fatiguing nature of the different industries and processes; determination of the causes of fatigue.

The two questions first mentioned may provide a most valuable contribution towards the solution of the problems of vocational guidance and selection. The last enables fatigue to be minimised if not eliminated by effort directed to cause the disappearance of the etiological factors of injurious fatigue. These derive from the nature of the work (duration, intensity, etc.), conditions of work (physical conditions of the work (duration, intensity, etc.), impersonal factors of the atmosphere and surroundings, among others of ventilation, lighting); impersonal factors of fatigue. They also bear upon methods of work: personal factors of fatigue.

Fatigue tests are divided into two categories:

(1) **Direct tests**, that is, those tests previously standardised which are applied to the subjects themselves. Of such a kind are the psycho-physiological, corresponding more particularly to the first two matters of consideration above referred to.

(2) **Indirect tests** utilising phenomena indicative of fatigue or influenced by the existence of fatigue. Of such are the industrial tests which correspond more particularly to the last-named class of consideration.

**Direct Tests: Psycho-physiological Methods**

This class of test calls in aid all the functions of the organism by methods of technique somewhat analogous to those used clinically, those used in experimental psychology, or in the determination of fitness for work in vocational guidance. Without wishing to enumerate all the tests used, the manner of applying which is described in numerous treatises, it will suffice to say that this class comprises physiological, chemical and psychological tests.

Among the physiological tests those of a neuromuscular nature are concerned with different qualities of muscular functions: strength and endurance (dynamometry and tests derived from it); sensory functions (aesthesiometry); precision (aiming and tracing tests); co-ordination and control (tremor, static equilibrium); muscular speed (tapping test); rapidity of reflex action (knee jerk).

The respiratory tests serve to study the changes in the movements in the respiratory effort and in the pulmonary air exchange (pneumography, breath-holding tests, spirometry).

The circulatory tests have for their object to determine changes in the arterial pressure, in the pulse, the quickness with which return to normal is reached in the case of arterial pressure and pulse after exercise, and the vasomotor reactions.

The vegetative tests include the measurement of the changes in the temperature and weight of the body, and of metabolism.

The various functions of the sense organs have furnished tests often used for determining cutaneous sensibility (aesthesiometry), muscular (sense of position, resistance), visual (visual acuity, visual field, power of accommodation, etc.), auditory (acuity of hearing).

The chemical tests are concerned with the state of the tissues (blood, urine), and the gases of the body (respiratory gases), in order to determine the changes in their constitution, whether it be a question of abnormal quantities of products normally present, or the appearance of abnormal substances by some regarded as “fatigue products”. These different tests demand minute and delicate laboratory equipment.

The psychological tests, finally, comprise psychomotor tests (study of the reaction time), and the intellectual and mental tests properly so-called, tests relating to attention, memory, reaction, logical faculty — carried out by means of numerous methods.

The different psycho-physiological tests are, for the rest, according to the principles on which they rely, either examination or executive tests. The former, sometimes called passive tests (“non-performance tests”), are intended to expose the supposed modifications in the organism characteristic of fatigue. They include the chemical and certain physiological tests (circulation and respiratory tests, etc.). The latter, sometimes called “active tests” (“performance tests”), consist in making the subject carry out a set piece of work the variations in the execution of which are considered to be proportional to the state of fatigue. Much the most numerous, they include the majority of the physiological tests (muscular tests), and the whole of the psychological tests; they only differ from the indirect tests of output in that they measure the execution of a job other than that of professional work.
**Indirect Tests: Industrial Tests**

These tests consist in studying by statistical methods phenomena considered to be indicative of fatigue. They utilise relative elements either connected with work (output, spoiled work, consumption of motive power, lost time), or with the workers themselves (accidents, morbidity, mortality, labour turnover).

The output test, which is the one most employed, has for its object to determine the value and variations in the quantity of work done in units of defined time (hour, day, week, etc.). According to the particular case the units of output are expressed in different ways (number of units turned out, time necessary for the production of the unit in question). This test, easily employed, is at the same time limited to processes permitting enumeration of identical units of production or which can be made so by calculation. The method of sampling consists in studying the output of a given operation by testing it during a period of regular working. The use of the test depends equally on the nature of the work and the part played in its production by the human factor, the maximum influence of which occurs in manual work and is nil in an automatic process. The test can neither be applied to operations which are largely automatic nor to those in which output is affected by factors external to the person concerned (telephone assistants).

Diminution in output usually signifies an increase in fatigue, with the reservation, however, of account being taken of disturbing factors which, apart from fatigue, may cause the output to vary, or of those which might exaggerate or weaken the effects of fatigue on it.

The test of spoiled work is concerned with the quality of the work in determining the proportion of rejects and mistakes in the total output. Used principally in repetitive processes in the making of small articles, this test, analogous in technique to the preceding one, yields similar results, that is to say, an increase in the percentage of spoiled work pari passu with increase of fatigue.

Under the name of tests relating to the quality of work, other means are used for operations the results of which cannot be expressed in terms of output or spoiled work; as, e.g., increase in the number and duration of rest pauses taken spontaneously in the course of work (Vernon, Farmer): differences in the composition of certain chemical products (Vernon).

The test of the consumption of motive power is concerned with the variations of this consumption during chosen periods of time. This test, giving results identical with the test from output, of which indeed it is a derivative, is only applicable in the case of mechanical operations where the power of the machinery to do its work (as regards speed) depends fundamentally upon the capacity for work of the personnel.

The test of lost time determines, in relation to the total hours of work, the value of time lost owing to voluntary absence from the place of work (excluding absences due to sickness or other adequate causes): it is more rarely used in consequence of mistakes in data from factory statistics and of disturbing influences external to the work.

The test of accidents, together with the output test, is the most used. The number and distribution of accidents found is determined in selected units of time, at the same time taking careful note of the hour of occurrence (and not the length thereof reported), and of the length of time the victim had worked prior to the accident. The results obtained enable a conclusion to be drawn as to the increase in the number of accidents under the influence of fatigue with the reservation that there may be other factors besides accidents, the relative importance of which has been appreciated differently by various authorities. The first factor is speed of production, an increase in which increases the risk of accident at the same time and necessitates bringing the accident figures into relation with output or consumption of motive power. Next there are the psychological factors (attention, negligence, etc.), the role of which may explain partly certain peculiarities in the accident curves relative to night work (Vernon). Attention has also been directed to such points as personal susceptibility (Peri, Greenwood), depending on age, state of health, experience of the work, consumption of alcohol, to the environment, the kind of work done, which may make for inequality in the risks and dangers run.

The majority of authorities are unanimous in agreeing that morbidity statistics probably indicate in the case of some workers a condition of extreme fatigue and, in many of them, a diminution in the capacity for work. Some authorities even think that "fatigue plays, as a principal etiological factor or as one favouring disease, a role even more important than any other element." (Sir James Paget).

The data necessary are furnished either by statistics kept by the factories
(duration of absence), or by insurance offices (number of sick persons, amount of sick benefit paid out). The results obtained are not always very clearly indicated by the number of disturbing factors causing the true morbidity figure and index of morbidity to fluctuate. It would seem necessary to limit the use of this test to a comparison of the different departments of the same factory, and even in this restricted domain the results can only serve as an indication of the possible existence of fatigue, which would then have to be studied by other methods (Wilson).

Mortality statistics have only rarely been utilised because of the difficulties of establishing them and interpreting them. Their use is further limited by the same considerations and the same conclusions as have been described in the case of the previous test.

The labour turnover, which acts as an indication of the degree of inadaptability of the personnel to a given task, can be utilised in the measure in which this interpretation depends on fatigue peculiar to the work. The test consists in determining over selected periods of time the number of persons who have left the work, the length of time prior to leaving, and the reasons for their going.

The numerical expression of the turnover is got at by bringing them into relation with the total personnel and many formulas for calculating it have been worked out (S. Florence, Broughton, Newbold, Alien, Alexander). This test is especially useful as a complement to those which have just been described, the more so because numerous causes, physiological, pathological, psychological, economical and social, affect labour turnover much sooner than does fatigue.

The various industrial tests, especially those of output, are utilised either discontinuously or continuously. In the first case there are compared the results furnished before and after the coming into play of an etiological factor the influence of which it is desired to determine. In the second case, their variations are studied during a specified period of time, bearing in mind, again at the same time, the different conditions existing in regard to the work. Use of one or other of these methods or even of the two concurrently, when that is possible, depends on the particular circumstances of the enquiry.

Without wishing to enter into theoretical considerations for determining if the present state of knowledge of the physiology of fatigue permits of adequate methods of measurement, there is no doubt that, at the present time, despite the large amount of research engaged in, the psycho-physiological tests have not yielded the results anticipated, nor have they furnished, in any case, a technique suitable for practical application. The simplicity and relative rapidity in carrying them out does not compensate for the numerous causes of error. The principal defect is that the majority of them (tests of execution especially) are influenced by the will of the subject and by numerous disturbing factors which invalidate the results obtained from them.

The industrial tests are very much more difficult to carry out and are more delicate to interpret. But seeing that the study of industrial fatigue on the spot is directed especially to ascertaining its cause, more and more frequent recourse is had to them. The constancy of the data yielded by their technique relative to the relation between the results they furnish and the varying working conditions accompanying them seems to single out these tests as the best adapted for obtaining the precise data which alone permit of rapid realisation of practical results in the prevention and elimination of industrial fatigue.

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Feathers


Feathers which cover the bodies of birds are formed of a substance similar to that of the hair, horn, nails, etc., of other animals. They consist in a kind of small stick (calamus) hollow at the base, from the sides of which spreading branches grow out, which, in their turn, serve for the insertion of still finer branches. Feathers may be
subdivided into feathers properly so-called, which are the largest elements found in the wings and tails of the birds, and plumage, which is lighter and more flexible, and covers the whole body, and finally, down, comprising the finest elements, which are inserted directly into the skin. This alone forms the covering of the bodies of young birds.

Amongst birds furnishing rare plumage may be mentioned the heron, the swan, the pheasant, the marabou, the bird of paradise, the humming bird, the egret, etc.

Feathers and plumage are placed on the market either in the crude state or subsequent to cleaning and removal of fat. The latter process consists in simple washing in soapy water or in treatment by boiling water and starch, or boiling water containing a kind of whitening which impregnates the feathers and increases their weight. The feathers are further subjected to bleaching, which is usually done by means of sulphur dioxide or hydrogen peroxide. Dyeing of feathers is effected by means of different colours (tar, vegetable or mineral colours).

Feathers also undergo curling, which is effected by passing them between the thumb and a blunt knife edge. Finally, feathers are treated in several other ways, such as gluing on to light materials to imitate the plumage of birds, etc.

Imitation of the plumage of rarer birds (egrets, birds of paradise) is fairly currently effected in industry. In general, rare plumes or imitations of plumes are utilised for decoration, and the others, as well as plumage and especially down, for the filling of cushions, eiderdown quilts, mattresses, etc.

**Pathology**

The various occupations in which workers are obliged to handle feathers are considered amongst the most unhealthy. Whether it be a case of women workers in factories producing fancy feather goods, coloured or otherwise, or mattress makers engaged in stuffing mattresses, cushions, eiderdowns, etc., the risks incurred are the same. There has been mentioned as of first importance the dust given off in course of the various operations, and especially during the beating of the feathers. Such dusts have often a suffocating effect, and are said in certain cases to have given rise to ophthalmia. Apart from this, the handling of feathers involves the risk of infection (notably that of erysipelas, scarlet fever, diphtheria, and typhoid fever), especially where it is a question of re-feathering of non-disinfected bedding belonging to patients with infectious diseases. Besides such affections, to which chiefly mattress makers are exposed, mention should be made of smallpox, which may be incurred by all categories of workers engaged non-disinfected feathers coming from abroad. Tuberculosis has been reported as a disease affecting fairly frequently workers engaged in handling feathers, and is said to be due, in the first instance, to the low constitutional state often found amongst these workers, and in the second place, to the presence of dust capable of carrying infective agents or of predisposing the system to contamination by reason of the irritation which it produces in the respiratory passages.

Amongst other sources of risk it is necessary to recall the possibility of poisoning by colouring matter used in dyeing, as well as by substances used for bleaching.

Finally, parasitical infection may be contracted by contact with non-disinfected feathers. There have been reported cases of workers affected by itch-mites, bird lice, fleas, etc.

**Hygiene**

The work, and especially the beating of feathers for mattresses and bedding, is generally carried on in the same establishment in which wool, horsehair and skins are handled. It is for this reason that hygienic measures relating to feathers and down are in general those issued relative to wool and horsehair:

Workrooms to be constructed of incombustible material with impermeable walls coated with oil paint; effective ventilation of the workrooms by exhaust system, with removal of dust to hearths or damped chambers; lighting of the workrooms by lights situated externally or having a double covering; precautions as to the situation of hearths and gas or petrol motors; wire netting on windows and apertures; precautions against the noise of beating machines; operations of beating to be carried out in hermetically sealed apparatus, or placed under a hood arranged in such a manner that exhaust draught removes the dust to a hearth or damped chamber; disinfection of the raw material where it is of suspect origin; measures of personal hygiene for the workers (working clothes, masks if necessary, headgear washing facilities and douches, etc.).
As regards disinfection of feathers; this may be effected by superheated steam without damaging the plumage.

Legislation
Young persons under sixteen years of age are excluded from the cleaning, beating and preparation of feathers and down when dust is freely given off in the workroom, in Belgium; in Spain, boys under sixteen and women under twenty-one; in France, young persons under eighteen; in Italy, boys under fifteen and women under twenty-one, etc. In the Netherlands, women and young persons are not admitted to the work (cleaning of feathers) unless the factory inspectorate can certify that there is no danger of liberation of dust in the workroom and that the cubic space per worker is not inferior to 10 cubic metres, of which at least 4 cubic metres exceed a height of 1.80 metres.

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Felt Hat Industry
French: Industrie des chapeaux de feutre.

Industrial Operations
The felt hat industry is divided into three stages, of which the first — preparation of the raw skins, "carotting", and sometimes "blowing" and packing the furs — is often carried on in another factory (see article "Hatters Furriers' Processes").

The two other branches — manufacture of the felt and finishing — comprise the following principal operations:

(a) Storage of the Fur
When the fur (of the hare, rabbit, beaver, mole) arrives, without having passed through the blowing machine, the hat factories receive it in the condition in which it left the cutting machine, packed in paper bags. Under these conditions it is still possible to recognise the outline of the animal and to know immediately if that part of the fur has been sent which covered the inferior parts (paws and tail of the animal). These inferior parts, whether carotted or not, are only used for mixing with good hair in the manufacture of hats of poor quality. For such qualities, too, hair of the dog, cat, calf, ox, and even of the camel, is used.

During storage, the fur loses an appreciable quantity of mercury (Biot, Heucke, Teleky) and it is recognised that the men in the storage room are exposed to mercurialism in an unusual degree, especially if the rooms are not well ventilated.

(b) Mixing and Blowing
According to the quality of the hat desired, different varieties of fur are mixed either with a hand tool (rarely now) or by an American machine known as a "devil". From the mixture obtained, all that can be regarded as waste or as too hard is eliminated by blowing. This operation is carried out in a long casing of wood and glass provided with a series of compartments enclosed in fine wire netting, through which passes a travelling endless apron carrying in the fur. A current of air set up by the rotation of the pickers lifts the fur, separates it, and tosses it into the air. The heavier hair and dust fall into a space between the endless apron and picker, while the finer fur is carried on further. The quantity of fur which is thus carried on varies according to its quality (its length) and according to the rapidity of the revolution of the pickers. During this operation the fur has a tendency to become felted over the inner surface of the netting, so that it is necessary to clear it away by beating, either by hand or mechanically, the outside of the machine. Blocking of the blower by the fur is also prevented by introducing a certain amount of moisture provided by a jet of steam. The machine requires to be frequently cleaned.

Dangers. The risk of mercurial poisoning at this phase of the manufacture is fairly great. In 100 gr. of dust from the blowing machine Teleky found 2.338 mg. of mercury, and calculates that a cubic metre of air might contain up to 40 mg. He estimates, though, that a fraction only (from 1:20 to 1:100) is soluble in the gastric juice, and so capable of being absorbed into the system. The risk of mercurialism exists, and nobody denies it; but the injurious effect of the fine fur dust — apart from the presence of mercury — is a matter of controversy. Some authorities (Schuette, Germany, for example) consider it to be injurious and a serious risk to health when present in enormous quantities, as is the case in the operations of mixing and blowing. Others, on the other hand (Gilbert, Belgium, and Wright, United States) find no injury to the lungs traceable.
to this dust. The discomfort induced in the upper air passages is, however, undeniable, and the general condition of the atmosphere to be found in many workrooms augments still further their already detrimental state from a health standpoint (thus, e.g., the blowing rooms in the United States are sometimes excessively humidified).

Hygiene. Dispersal of the fur should be prevented either by covering the machines with a heavy hood (of glass or oilcloth) or by so adjusting the rate of revolution of the pickers as to diminish the rapidity of the draught. Humidity should not be practised more than is necessary (thus in Italy the natural humidity of the air is considered sufficient). The Labour Department of New Jersey (U.S.A.) considers that humidification is unnecessary, except in cold weather, and should never exceed 65-75 per cent. At all events, steam should be delivered into the blowing machine rather than into the room itself. In Belgium, regulations prescribe that the air which has passed through the blowing machines must not enter the workroom.

(c) Weighing and Forming

The blown fur is weighed to a quantity sufficient for a hat and carried on a travelling apron to the upper part of the forming machine. By means of a current of air, this machine separates the mass of fur and allows it to fall in a fine state of subdivision on a large copper cone pierced by very fine holes, which, in well-arranged factories, is confined in a little glass chamber. Below the cone a very strong draught is maintained and at the same time the upper part of the cone is kept moist by a jet of warm water.

The fur, carried down by the current of air from the top of the chamber against the cone and sucked on to it by the draught below, distributes itself uniformly over the surface. The warm water favours this preliminary agglomera-

Fig. 96. — A series of blowing machines at the establishments of Messrs. Borsalino Glus. and Bros. (Alessandria, Italy).
covered with a piece of cloth wrung out of hot water, and a similar copper cone is fitted over it and the whole plunged into boiling water. The process described is that ordinarily practised (the so-called "tell" process), but felting can also be done by hand.

The form, wrapped in cloth, is then removed and sent to the inspector and hardener.

(d) Hardening

This operation consists in shrinking and kneading at the same time about

and the shrinking processes about 22 per cent.

Hygiene. Measures should be taken to prevent steam and an unduly high temperature. The floor should be impermeable, with channels to remove the streams of water from the machines. The workers should be provided with clogs and overalls. In small and especially in very small premises young persons are sometimes occupied in weighing the fur in the same room in which forming is done. This should be avoided and the two

Fig. 9 - Forming machines at the establishment of Messrs. Borsalino, Cline, and Bros. Alessandria, Italy.

six forms in preparation for shrinking and planking. The work is very arduous, especially in American factories, because it is carried out almost without interruption in hot workrooms, full of steam and wet underfoot. Analyses of the air from the forming machines have shown noticeable traces of mercury. These machines, as described above, allow dust to escape when they are opened.

The fur, which in storing has already lost 49 per cent. of the mercury absorbed in carotting, loses in this process entirely separated, the rooms communicating with the forming machines by pipes into which the weighted hair can be dropped.

(e) Planking or Sizing

After inspection the felt form goes to the planking room, where it undergoes a series of operations known under the name of "starting", "wetting down", "pulling out", "sizing", "blocking", "wringing", etc., all of which have for their principal object...
to make the felt thicker, more resist-
tant and more compact. The form
becomes gradually smaller, and when
forming is complete the work of
shaping commences, designed to
provide the form with the desired
shape and dimensions.

Dangers. Whether done by hand or
machines of different kinds, the three
stages of sizing constitute very arduous
labour carried out in a hot and humid
atmosphere. The hand planker has
his hands continually in very hot
water, usually slightly acidulated
with sulphuric acid (about 2 per 1,000)
or lactic or acetic acid, and he must
exert very strong pressure on the felt
with his palms. From time to time
he is obliged to dip his hands in cold
water. The hot water and the sizing
vessels give off much steam, which
condenses on the walls and ceiling and
runs in streams on the floor. The
problem of ventilation is particularly
difficult in countries with a variable
climate. In some factories for certain
kinds of hats, dyes are added to the
sizing water so as to dye the felt at
the same time. The dyes generally
belong to the group of amino deriv-
atives and do not represent any
important additional source of danger.

In addition to the steam, humidity
and excessive heat, the workers in this
department are exposed to the danger
of mercurial absorption. Indeed, droplets
of metallic mercury have been
found at the bottom of the vats (Monti,
Teleky); they can therefore become
volatilised from the hot water, which
contains appreciable traces of mercury
(whence it has been detected in the urine
of sizers even two months after cessa-
tion from work).

Very thickened callosities on the
thenar and hypothenar eminences of
the hands of sizers were described as
far back as 1862 by Max Vernois. The
skin of these parts is often red and
sensitive as a result of the pressure
of the hands on the edges of the sizing
vat and from the action of the liquids
in which the felled mass is soaked.
Lesions on the nails, which suppurate
rather rapidly, cases of paronychia,
and eczema were described in 1898 by
Grégoire and confirmed by Teleky in
1907. They are due to the use of lactic
acid, for they are lessened or disappear
if sulphuric acid of good quality, or
even acetic acid, replace it (Heucke).
The callosities appear also on the dorsal
sides of the fingers. Artom (1923)
considers that this epidermal reaction
of hyperkeratosic type of the hands
of sizers is due to the mechanical rubbing
of the palm against a hard body rather
than to any physico-chemical action of
the acid liquor in the vats. There is an
early phenomenon accompanied by
burning sensation, itching, and pain
on pressure. Painful complications
(rhagades) are fairly frequent and
require a long rest.

Hygiene. The requirements are:
good ventilation of the room, suppres-
sion as far as possible of the escape of
steam by fixing hoods over the vats,
and sizing apparatus, etc., containing
hot water, connected up to a powerful
system of exhaust ventilation combined
with a plenum system for blowing in
hot air as in the case of linen fac-
tories; openings no larger than the work
requires to allow of the introduction
of the felt forms. Kettles used by hand
sizers should be protected by a hood
with an exhaust pipe and a curtain
composed of flaps of heavy canvas
hanging from the edge of the hood to
the edge of the kettle, the sizer pushing
the form under the flap. Sizing
machines should be emptied and
cleaned as often as possible; work
should be alternated with less arduous
work. Women and persons showing
excessive susceptibility to eczema
and dermatitis should be excluded.
Measures to avoid skin lesions and
poisonings from the dyes used should
be taken. Wooden bats or rubber
gloves should be used to protect the
hands.

(I) Dyeing

This may be done at several different
stages of the manufacture. For coloured
hats, the plain fur can be dyed
before the hat is formed, or the dye
may be added to the water in the
sizing vat. The ordinary way is to
dye the body. A preliminary mordant-
inhaling bath, generally of dichromate
of potassium, is applied either in open
vessels where they are stirred by
hand with long wooden rods, or in
closed kettles agitated by a current
of air, or again in closed revolving
cylinders which dip down into the
dye at each revolution. A second
sizing may follow dyeing.

Dangers. Besides the humidity
and heat which accompany this operation,
the use of certain coal tar dyes may
set up — especially when added to the
sizing water — skin lesions (on the
hands and especially the fingers),
paronychia and suppurative inflamma-
tion of small cuts and injuries. The
use of ursol (paraphenylene-diamine)
may cause not only severe dermatitis
but attacks of bronchial asthma.
Chrome solutions — usually very dilute
only rarely set up ulceration of the fingers or of the nasal mucous membrane and conjunctivitis. They are generally found only in the workmen preparing the solutions in question (see articles "Chromates" and "Paraphenylenediamine").

Hygiene. Measures should be taken to avoid humidity, both in regard to the workroom and the individual workman; mordanting and dyeing should be done in closed apparatus only. The use of ursol should be avoided.

Stiffening

A long series of operations serves to modify the shape of the felt body; special machines render it dome-shaped; others (if the work is not done by hand) shape the brims. For soft felt hats the stiffening process is of no importance, because the stiffening compound is only shellac dissolved in hot water, borax and common salt rubbed in with a brush and then submitted to steam to melt the shellac and drive it into the felt. The majority of American hats are soft, but in Europe many hard felt hats are worn. For these, shellac dissolved in methylated spirits is used, which may contain from 2-20 per cent. of methyl alcohol. The quality of methylated spirit employed in America contains 10 per cent.

Dangers. Methyl alcohol, pyridine, and mercury are the risks to which the workers in this section are exposed. They are analogous to those in the preceding department, but not so pronounced. Mercury has been recovered after drying.

Hygiene. Use of methylated spirits containing as little pyridine or methyl alcohol as possible; free ventilation of the stiffening department and enclosed drying chambers, so arranged that the hats can be moved without requiring the workman to go inside.

**Fig. 100. System of machines with localised exhaust for dust removal**

Valera and Ricci, Monza, Italy.

(h) Pouncing or Shaving

This operation consists in hand or machine rubbing the felt hats (soft or hard) by the use of fine glass paper. Pouncing the soft felt hat is much more arduous and produces much more dust than that of the hard. Mechanical methods reduce the risk of dust, and it is easier to adopt locally applied exhaust ventilation to the machines.

Danger. Very fine dust containing silica produced by the glass paper and mercury constitutes the chief risk. Teleky has found 2.19 mg. per
Statistics

In most countries the statistics of occupational diseases among hatters do not distinguish between the manufacture and finishing of the hats and the cases in hatters’ furriers’ processes. The French, Belgian, German, Austrian, and Italian statistics generally include both these branches of manufacture, and it is in general the same for the British and American reports. When the two branches are separated frequency and severity are generally much higher in the furriers’ trade than in hat making. This is not, however, quite borne out by the statistics in the Medical Inspector’s report in Great Britain, which shows that of 45 cases of mercurial poisoning between 1900 and 1933, 24 occurred in the furriers’ trade, and 21 in the hatters’. An analysis of the data in medical literature shows the following facts:

**Austria.** — The hat industry is carried on in this country often in small workshops, even in the big towns. If cases of mercurialism were very frequent before 1892, they have certainly diminished in number since then. The figures given for the period 1892-1905 have not much value, as they lack precision. They serve only to show the incidence of cellulitis, eczema, and fatalities from nephritis.

An inquiry carried out by Teleky in 1910 in two factorics, employing the one 2,400 persons and the other (in 1911) about 250, revealed in the first factory 15 relatively severe cases of mercurialism, with four others in which the persons affected were obliged to give up the work on account of the sequelae; in the second factory five cases only were found. The women were more often affected than the men.

The factory inspectors’ reports cite cases of eczema from sulphuric acid, cases of mercurialism especially among the blowers (1913); periodic medical examination, however, shows the possibility of avoiding all mercurial intoxication.

**Germany.** — The figures given by experts are few. Schütte has obtained from the registers of the Hatters’ Sickness Insurance Society of Magdeburg, Guben and Friedrichdorf for the last 10 years (relating to 1,000 male and female workers between 20 and 60 years of age) the following data:

- Respiratory diseases, 44.1, with mortality of 1.5. — Tuberculosis, 21.6, with mortality of 3.7. — Eye and ear diseases, 30. — Diseases of the digestive tract, 28. — Diseases of the nervous system, 21.6. — Poisonings, 22.5. — Lesions and burns, 18.1. — Diseases of the skin, 17.1. — Diseases of the circulatory system, 13.9, with mortality of 0.9.

The statistics of the local sickness insurance society in Leipzig for a group with less than 5,000 members show (taking as basis the average number of cases per 100 workers per annum for all industries = 1) the relative figures for the felt hat industry as a morbidity rate of 1.4 for all diseases, and the following rates for accidents and certain diseases: diseases of the locomotory apparatus, 2.6; nervous diseases,
United States. — Several investigations have taken place in the United States enabling distinctions to be made between the different branches of the trade, which was introduced into America in 1668. Inquiries conducted in 1859 and 1878 in New Jersey have brought to light the existence of a large number of cases of mercury poisoning. Conditions to-day have naturally improved. An investigation by Mrs. Linden Bates in New York and New Jersey (1912) into mercurial poisoning showed that the majority of the 103 reported cases were contracted in the hat trades, the precise occupations being 13 formers, 5 hardeners, and 12 sizers. A further investigation conducted in 1915 by Harris in New York related to 266 persons, of whom 110 were women. It should be added that this inquiry was made in a poor quarter, and many of the workers concerned were addicted to alcohol. Leaving out of account carotters, examination of 81 hatters, of whom 12 were women, showed 6 to have marked mercurial tremor, 7 less severe tremor, and in a slight tremor. Twelve men had anaemia, and three gingivitis.

Wright (in 1922) examined 92 working hatters in Connecticut, 69 of them engaged in making hats, and 23 in finishing. Of these workers 43 per cent. presented evidence of chronic mercurial poisoning. So far as respiratory diseases are concerned, Wright could not show any case of active tuberculosis. Radiographic examination of 56 per cent. did not reveal serious pulmonary lesions, in spite of numerous cases of marked infiltration of the pulmonary hilus and diminished transparency at one or both of the apices and in many persons of numerous glands affected and occasionally diffuse mottling.

On the other hand, Stickler draws attention to the frequency of tuberculosis among the hatters in Newark Orange (New Jersey) between 1873 and 1886, a frequency which reached 51.8 per cent. of all deaths among this class (375 deaths from tuberculosis, to 772 total deaths). The other causes of death attain the following values: Among 1224 hatters, respiratory diseases, 76; rheumatism, 44; cough, 41; tremor, 30. Among 27 pouncers, respiratory diseases, 12; cough, 4; tremor, 5. Among 292 finishers, respiratory diseases, 64; rheumatism, 16; cough, 42; tremor, 33. Further, 18 finishers showed signs of stomatitis, 7 of bronchitis, 4 of tuberculosis, and 1 of asthma.

Hoffmann has sought to determine the frequency of tuberculosis among American hat makers, and makes comparison between these workers and tailors. He shows that the former had higher ratios at all age groups, especially at the range group 35-44. Further, comparison of the percentage of mortality for all workers in the United States and 832 hatters works out as follows for tuberculosis:

<table>
<thead>
<tr>
<th>Age Range</th>
<th>All Males</th>
<th>Hatters</th>
</tr>
</thead>
<tbody>
<tr>
<td>From 15 to 24 years</td>
<td>27.8</td>
<td>31.1</td>
</tr>
<tr>
<td>25 to 34</td>
<td>25.6</td>
<td>35.4</td>
</tr>
<tr>
<td>35 to 44</td>
<td>33.6</td>
<td>45.4</td>
</tr>
<tr>
<td>45 to 54</td>
<td>15.0</td>
<td>20.7</td>
</tr>
<tr>
<td>55 to 64</td>
<td>8.1</td>
<td>14.6</td>
</tr>
</tbody>
</table>
According to the data of the Prudential Insurance Company, among 529 deaths of hatters 36.6 per cent. were due to pulmonary tuberculosis.

In conclusion, about 300 hatters examined 46 (or about 14 per cent.) showed characteristic symptoms of mercurialism (gingivitis, marked tremor of the hands, etc.) and the same percentage were affected by a slighter form of poisoning, accompanied by anaemia and arterio sclerosis. According to L. T. Bryant, this industry was so unhealthy as to deter insurance societies taking the risk, at no matter what premium, of insuring the workmen in the processes of sizing, forming, etc., and accepting workmen in other processes only on condition of payment of an extra premium.

PREVENTIVE MEASURES
The measures described after each process may be supplemented by measures generally prescribed in regard to the floors of workrooms, reduction or elimination of bad odours, danger of poisoning and of fire in varnishing and drying felt, and purification of the residual waters. Naturally, individual hygiene also plays its part.

LEGISLATION
[See the articles "Hair Cutting" and "Mercury".]

In Argentina, women and children are excluded from workrooms where varnishes are used and where the treatment of the fur gives rise to the evolution of dust.

In Belgium, young persons under sixteen years, in France under eighteen years, and in Spain male young persons under sixteen years and females under twenty-one years are excluded from rooms where dust is given off freely and where varnishes are prepared and used.

In Italy, male young persons of fifteen and females up to twenty-one years are excluded from the processes of pouncing, napping and brushing, when effective locally applied exhaust ventilation for the removal of dust is absent.

As regards notification of, and compensation for, industrial diseases, see articles "Hatters Furriers' Processes", and "Mercury".

There are no special regulations for the felt hat industry, health legislation only providing for measures against dust, smells, fire, and effluents.

In Austria, the Ministry of Interior issued on 29 November 1889 an order for the protection of the health of hat workers (carotters, blowers and plankers). On permission being given to start a hat factory in Vienna, the Medical Officer of Health laid down the hygienic measures to be applied in the carolling room (cited by Teleky).

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Dr. Alice Hamilton (Boston).

Ferrosilicon


PREPARATION

Ferrosilicon are combinations of iron and silicon corresponding to the formulae Fe₃Si and FeSi, which were first obtained in a blast furnace by reducing, at great heat, quartz containing iron to which sand is added, or better by using aluminous slags with 35 per cent. of silica and 25 per cent. of alumina, lime (which serves as a flux), baryta, and magnesia. In this process a third of the silicon is reduced, but the product obtained does not contain more than 10 to 15 per cent. of silicon.
Now it is obtained in an electric furnace by the reduction, by means of coal (or more frequently of coke), of a mixture of silica (sand and quartz) and iron ore (or steel turnings), or even sand alone with iron, which dissolves the silicon as it is made (thus allowing combinations with a proportion of 25, 50, 60, 80, and 95 per cent. of silicon).

In certain factories (in Switzerland) it is left exposed to the air so as to rid the ferrosilicon of its injurious gases. Then it is collected or put into barrels.

USES

Ferrosilicon is used in metallurgy in the preparation of silicon steel, in the refining of ordinary steels, in casting (because, as is the case with aluminium, it diminishes blowholes), in converting white cast-iron into grey, in the manufacture of electrodes, and as a means of polishing. According to Fellew, 9 tons of ferrosilicon could produce 195 grms. of phosphoretted hydrogen gas.

At the same time the mass becomes friable, falls into powder, and, with the greatly increased surface thus exposed, the quickness of the reaction is increased.

Ferrosilicon combines with water in very much the same way as calcium carbide (Zangger), and when phosphorus and arsenic are present yields arsenuretted and phosphoretted hydrogen gas.

On the other hand, according to other authorities (German Association of Blast Furnace Workers and German Association of Iron Casters), even when dry ferrosilicon sets free injurious gases formed during melting and present as such, in the alloy, whether in a state of solution or included in the molecular spaces between the crystals of the alloy. Liberation of these would take place when the ferrosilicon was decomposed, and would be due itself to the modifications of crystallisation and the texture of the alloy.

Whether this is the case or not, the stability of ferrosilicon depends on its content in silicon, because decomposition takes place especially in ferrosilicons containing 40 to 60 per cent. according to some, 30 to 70 per cent. according to others, of silicon, products with a higher content (above 70 per cent.) or lower (0-30 per cent.) being very stable.

According to Fellew, 31 cubic meters of toxic gases, but if the ferrosilicon is moist the quantity given off may be three times this.

In an enquiry made in Germany in 1921, it was found that at the ordinary temperature 100 kg. of ferrosilicon could produce 195 grms. of phosphoretted hydrogen gas.

POISONOUS ACTION

Ferrosilicon is a typical example of a substance, the toxicity of which is derived from the impurities contained in it. The raw materials used for its manufacture (coal and iron) contain, when impure, phosphorus and arsenic yielding, at the high temperature of the electrical furnace and in presence of lime, calcium arsenides and phosphides. These, in their turn, give off arsenuretted and phosphoretted hydrogen in the presence of moisture, sometimes sulphoretted hydrogen gas, and invariably acetylene; which explains the high degree of toxicity of the product.

The proportion of these gases is greater the more humidity there is, and when moisture is present may be three times this.

STATISTICS

The majority of the cases of poisoning have occurred among persons employed or living in confined spaces, on board ship or in barges or in conveying sacks of ferrosilicon.

In 1905, 50 cases of poisoning, with 11 deaths, occurred on a ship carrying ferrosilicon (Glaister), and 2 other fatal cases on a barge (Robertson); in 1908, 5 fatal cases occurred on an emigrant ship; 4 other fatal cases were reported by Cronquist. In 1913, 2 cases, one of which was fatal, occurred in Germany in the transport by barge of ferrosilicon. In 1920, 3 fatal cases were reported in Saxony among persons living in rooms situated above a ferrosilicon storeroom; in 1925, E. C. van Rijsel described 3 cases, one of which proved fatal, among children who had gone to sleep beside a load of ferrosilicon, etc.
SYMPTOMS

The symptoms of poisoning are analogous to those of arsenuiurated hydrogen or phosphoretted hydrogen or mixtures of them (see these articles).

Diagnosis is difficult, especially if the possibility of the absorption of these toxic substances is not borne in mind.

In considering the cases of poisoning by ferrosilicon it will be seen that before arriving at the right diagnosis such conditions as cholera, gastro-enteritis, ptomaine poisoning, pneumonia, influenza, etc., may be thought of.

DEMONSTRATION

For this, see articles "Arseniuretted Hydrogen" and "Sulphuretted Hydrogen". According to Copeman (quoted by Legge), indication of whether a sample will give off much gas is revealed by special nitrate of silver papers.

HYGIENE

The hygienic measures which have been recommended or enforced in recent years are the following:

Exclusion from use of impure or imperfectly prepared ferrosilicon.

Ferrosilicon should be kept in airtight (cast-iron) boxes away from moisture both during storage and transport. Ferrosilicon and its receptacles or other means of packing should be completely dry, the receptacles impermeable and solidly constructed so as to prevent possibility of all damage during transport.

Ferrosilicon should be stored in places absolutely dry and free from damp.

Thorough ventilation of storehouses and holds in which it is carried should be arranged. Care should be taken that the gas escaping through the ventilation shafts does not spread to places where persons live (as, e.g., cabins on barges and ships, etc.) and cabins and living quarters should not be allowed to communicate with places where ferrosilicon is stored.

Work in the storehouse should not be done until the room has been ventilated. Zanger recommends that it be under lock and key, and that no one shall be allowed inside without a permit from the responsible parties after effective renewal of the air.

Masters or persons carrying ferrosilicon ought not only to take all necessary measures of safety, but also to instruct all persons manipulating the product as to the risk.

These measures are included in a resolution adopted by the Seventh Assembly of the International Association for Labour Legislation (September 1912). The following recommendations suggested by Copeman might also well be adopted: breaking up of ferrosilicon into pieces of the size required at the place where it is used; exposure to the air in a sheltered place for a month at least before loading on to ships; prohibition of transport on passenger ships or on the top of the cargoes — it should be carried on deck or, if this cannot be managed, then in holds carefully ventilated and separated by airtight doors from living quarters; application of these measures in transport on barges in inland waters; packing cases containing ferrosilicon should have inscribed on them clear particulars concerning the material, such as the percentage of silicon, the date of the manufacture, and the place of origin.

LEGISLATION

Some countries have issued regulations as to the transport of ferrosilicon. Thus Prussia, by Regulations dated 9 December 1918, prescribed that packing should be done in wooden or metal cases impermeable to water; the following precautionary notice be inscribed "Ferrosilicon: To Be Kept Dry; Handle With Care": obligation to deliver the ferrosilicon in a dry state in boxes; to place the cases during transport in airy places on deck protected from moisture. A leaflet giving necessary instructions to workpeople has also been published by the Prussian Minister of Commerce.

In Saxony Regulations, dated 8 June 1907, as to the transport of ferrosilicon by railway and boats, as well as to the storage of the material, are in force. The following are the principal requirements; to keep the ferrosilicon dry; prohibition of its transport in small barrels, in confined spaces, or in the holds of vessels; compulsory ventilation of the storehouses which ought to be away from inhabited premises.

In addition to the above, the following special measures relating to transport and storing of ferrosilicon should be mentioned. Netherlands: Police Regulations drawn up by the Central Committee for Navigation on the Rhine; Notices issued by the Medical Authorities at Rotterdam. Germany: Regulations issued by the town of Bremen (No. 13 of 17 May 1912); Notice published by the Seamen's Union (See- Berufsgenossenschaft), Hamburg (2 September 1909); Regulations issued by the German Railways. Norway: certain sections in the Acts of 9 June 1903 deal with loading of dangerous products including the product in question. Sweden: regulations laying down conditions in regard to maritime and railway transport
of the product. Great Britain: transport of the product is subject to certain articles embodied in the Merchant and Shipping Acts, 1894 and 1906, and the product is also made the subject of detailed instructions in a Memorandum relating to the maritime transport of dangerous merchandise and explosives published by the Board of Trade in 1921.

The suggestion of making an international Convention to prevent poisoning by ferrosilicon, first proposed by Rambousek in 1910, and in 1912 by the International Association for Labour Legislation, was recently brought before the International Congress for Accidents and Industrial Diseases (Amsterdam, 1925).

Prof. H. Zanger (Zurich).

Fertilisers and Manures


TECHNICAL FACTS

Under the name of manures are included animal, vegetable or mineral matter, used to enrich cultivated ground so as to supply it with the elements necessary for the growth of plants. According to their active elements, manures are designated as being nitrogenous, or phosphatic, or potassium or calcareous. Commercial manures generally contain several of these active elements. Their number is increasing continually, so only the most important shall be dealt with here.

Among animal manures may be mentioned dung and liquid manure, used as such by farmers, guano, manures prepared from the scraps and refuse of meat and fish, dried excrement (poudrette), dried blood, slaughter-house refuse, powdered silkworm chrysalides, powdered bones and bone ash, night soil, and refuse from leather, horn, hooves or wool.

Guano is formed from the excrement of sea birds which has accumulated in enormous masses, from 50 to 60 metres thick, along the coasts of Peru and especially of Chile, in Patagonia, New Caledonia, and on certain points of the southern coast of Africa. It is found in the form of an agglomeration of material, varying in size, mixed with a powdery substance and debris from feathers; it is of a pale yellowish or brown colour, and has a decided ammoniacal odour. The superiority of guano as manure comes from the products it contains, including nitrogen, phosphoric and nitric acids, potassium, ammonical salts, and guanine. But Peruvian guano, which is the kind most sought after, varies in composition according to the bird which has produced it, the place where it has been deposited, the period of its formation, the thickness of the layer, and the quantity of feathers it contains. The commercial product is often adulterated with soil of the same colour, clay, plaster, or ashes from coal.

In practice artificial guano is made from refuse of animal bodies and entrails, and from carcasses of whales and fish, from which the fat has been extracted.

Refuse from the fish industry is used in the manufacture of fish guano; it is cooked and pressed to extract the oil; sometimes it is put in an autoclave in order to extract the gelatine, then the slabs are roasted, crushed, sifted and put in bags.

"Poudrette", which is known commercially as artificial guano, or "German guano", is made from dried excrement mixed with earth, dust, charcoal and ashes; it occurs as a brown, hygroscopic, powdery mass, containing phosphoric acid, potash and lime. It is prepared wholesale from the material taken from sewers, as well as from the beds of settling tanks for sewage. The material is received into tanks or separating reservoirs; the ammoniacal water is decanted; the pasty material, after being raised by a dredge and dried in the air, gives poudrette. In these days this material is treated by lime; the ammonia is recovered and the residue is dried.

Blood from abattoirs is cooked in an autoclave, dried in a stove, and crushed under millstones. In another process it is mixed with sulphate of iron and such acids as nitric and sulphuric; then it is dried, crushed and put into bags. Fresh or raw bones are ground, powder from degelatinised bones, or sawdust from making fancy goods out of bones, are also used.

The average composition of some of these manures is given in percentages as follows:

<table>
<thead>
<tr>
<th></th>
<th>Water</th>
<th>Total nitrogen</th>
<th>Phosphoric acid</th>
<th>Oxide of potassium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw guano</td>
<td>55-55.5</td>
<td>5.7-14</td>
<td>0.6-2</td>
<td></td>
</tr>
<tr>
<td>Commercial guano</td>
<td>14</td>
<td>12-14</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Commercial poudrette</td>
<td>8</td>
<td>0.6-0.8</td>
<td>0.5-0.5</td>
<td></td>
</tr>
<tr>
<td>Dung</td>
<td>60-69</td>
<td>0.6-0.8</td>
<td>0.5-1.5</td>
<td>0.6-0.8</td>
</tr>
<tr>
<td>Dried blood</td>
<td>10-12</td>
<td>9.5</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>Chrysalides</td>
<td>10</td>
<td>1</td>
<td>—</td>
<td></td>
</tr>
</tbody>
</table>
Various refuse, such as old boots, horsehair, feathers, down and wool, is also used as manure after having been roasted, crushed and sifted. Works for making manures of animal origin also carry on the manufacture of glues and gelatine as a by-product.

Among vegetable manures, the chief are cakes of oleaginous fats and residues from pressing grain remaining at the bottom of presses after the extraction of oil. The cakes are generally compact discs of varying sizes, about 30-40 cm. in diameter and 2-3 cm. thick, or rectangular cakes with sharp or rounded angles. They are handled in commerce in this state, or somewhat coarsely powdered. They are composed chiefly of all the solid part of the grain, that is to say, the woody, albuminoid, starchy and mineral substances, as well as of a certain amount of fatty matter. The value of the cakes depends on their content in nitrogen and phosphoric anhydride. They are defatted by means of solvents as sulphide of carbon, trichlorethylene or ether, in order to extract the oil; then they are broken and put into bags. They are often adulterated with finely ground grape pips, powdered olive kernels, husks of rice, and shells of ground-nuts.

Among vegetable manures mention should be made of seaweed manure, made from marine plants dried in the oven and then crushed; and also from ashes from the calcination of these plants in open trenches. Ashes of peat moss are also used (Picardy ashes), as well as the residue of crushed olives, vinasse, barley refuse, the sweepings of flour mills, and shells of duum of crushed olives, vinasse, barley, etc.

Mineral or chemical manures either occur naturally or are prepared artificially; they represent the most important products of the following categories exist: nitrogenous manures including such ammonical salts as sulphate and nitrate of ammonia, cyanamide of calcium urea, phosphate of urea, and nitrates; phosphatic manures with a base either of tricalcic phosphates, e.g. phosphoric, apatite, natural phosphates, and bone ashes; or of bicalcic phosphates, e.g. Thomas slag, precipitated phosphates, and phosphates of aluminium; or of monocalcic phosphates, e.g. mineral superphosphates and bone phosphates; potassium manures, combined or uncombined with gypsum, e.g. salts extracted from sea water, or saline strata; chlorides; leucite; various potassium mixtures; sylsite; kaolinite; calcareous manures which supply lime, e.g. chalk, marine calcareous deposits, gypsum, and lime from the sugar factories; various manures, industrial residues, cakes made from dregs, from tartrates, from iron salts, magnesia, or earth containing pyrites; manures made from roasting domestic excrement and that from the streets.

Natural phosphates are washed, sorted, crushed and then sifted; those obtained from residues in the manufacture of various chemical products are crushed and used for agricultural purposes. Thomas slag comes from the treatment of cast iron containing phosphorus (see article “Basic Slag”).

For the preparation of phosphated earths, earth which is somewhat deficient in phosphoric acid is enriched.

As regards superphosphates, see article “Superphosphates Industry”.

A new source of mineral manure (containing potassium) is to-day represented by leucite alumi-potassic silicate which abounds in the extinct volcanoes of Italy (central and south). An Italian process renders possible by means of an ingenious technical method the separation of the grains of leucite from the basalt mass. By this process the leucite which is first attacked by acids (hydrochloric or neutric) furnishes amongst other products chlorine or nitrate of potassium.

Generally speaking, this industry is run at high pressure during certain periods of the year when the work of preparing the land for sowing is in progress; during these periods the industry absorbs a large number of workers who are naturally unskilled labourers.

Sources of Dangers

The handling of such animal manures as dung, or liquid manure, either during industrial operations or during their use, is the cause of much trouble due to offensive smells, to the liberation of gas and poisonous fumes, e.g. carbon dioxide and ammoniacal gas; and to such pathogenic agents as anthrax, glanders, tetanus, typhoid fever, erysipelas, septicæmia and suppuration. Prosser-White quotes that Scopulariopsis Koninigi, which is found in manures, may be the cause of "trench foot".

When various animal products, such as refuse from slaughter houses, are being heated, workmen are exposed to the vapour, to nauseating smells and irritating fumes (see further on).

During the different operations of acidulation, and the extraction of fats, glue and gelatine, the various products used often cause trouble, such as poisoning by solvents, e.g. benzene, ether, trichlorethylene, carbon bisulphide and petrol, and by sulphuric and nitric acids. High wet-bulb temperatures also may exert a deleterious influence.

The various industrial operations set free a large number of products which are all more or less toxic. It is sufficient to mention the fumes and gases given off when phosphates are dissolved by sulphuric acid, i.e. fumes of hydrochloric, hydrofluoric and fluosilicic acids; carbon dioxide, sulphurous anhydride; sulphuretted hydrogen and arseniuretted hydrogen. Sometimes nitrous fumes are evolved when Chile
salt peter is mixed with strongly acid superphosphates. Tri- and dimethyl-amine, ammonia and monomethylamine are set free by decomposing animal products. Acrolein and acid fats are released when abattoir refuse or fats of animal origin are boiled.

A case of poisoning by arseniuretted hydrogen has been reported in a workman who handled some slime containing arsenical sulphuric acid. Hydrofluoric acid which is given off during the operation of treating such natural phosphates as phosphorite or apatite with sulphuric acid, has caused chronic diseases of the respiratory passages and very serious dermatitis. The window glass of the factory was attacked as high as 8 metres from the ground.

The operations of crushing, acidulation, mixing and, especially, of packing in bags, raise great quantities of dust, some of which has a very irritating and caustic action on the mucous membranes and skin. This action occurs particularly with nitrate manures which have a basis of lime, phosphates and cyanamide. (See articles "Basic Slag", "Superphosphates Industry", "Calcium Cyanamide", etc.)

Quite recently (1928), M. Letulle and L. Vinay have formulated the suggestion that proof of an injurious role played by a diet too rich in potassium predominates among young persons. The question is raised whether the excessive use of chemical manure — in which nitrate of potassium predominates — does not in some way influence this recurrence of cancerous affections. As a matter of fact cereals, potatoes, meat and milk, raised by intensive culture, which form an important part of the food of the people, owing to the land being manured artificially, contain a considerable proportion of potassium salts which come from chemical manures.

Risks of fire and explosion exist, due not only to dust given off by certain manures, but also to the presence in manure works of inflammatory products, such as nitrates and solvents.

In Germany at Aachen, an explosion in a manure warehouse killed 19 persons and injured 15 others more or less seriously. It was caused by nitrate of potassium and ammonium, containing 50 per cent. kainite, 5 per cent. sand and 45 per cent. ammonal, which is an explosive having as its basis nitrate of ammonium and aluminium, with trinitrotoluene.

The use of tanks lined with lead has often exposed workmen to lead poisoning during soldering and repairs; the presence of arsenic in artificial manures has also been the cause of dermatitis.

### Statistics

Numerous statistics on the injuries caused by manures are not available. In Germany in 1908 a case of ulceration of the genital organs was noted in a man employed in drying phosphate of soda. Richerand has reported a case of cancer of the testicle in a man handling guano.

In Germany, several cases of anthrax have been noted in the Potsdam district in animal manure works (Both); in the United States, some cases of tetanus (Hayhurst); in Great Britain, 5 cases of anthrax in 1913, one of which was fatal. Several cases of septicaemic infection, one of which was fatal, have been submitted in Germany to arbitration for legal compensation of injuries.

In Austria (1914-1918) a fatal case of poisoning was noted affecting a workman at an artificial manure factory, who had entered an empty oil tank before it had been finally cleaned. In Holland (1923) 19 cases of dermatitis due to artificial manures were reported.

### Pathology

Bad smells bring on anorexia, headaches, malaise, sometimes vomiting, diarrhoea, general depression and weakness in workmen in these industries. Infectious agents can cause all kinds of diseases: typhoid fever, septicaemia, anthrax, tetanus, glanders and infection of wounds. Such emanations from manure works as ammonia and ammonium sulphide, are injurious because, according to laboratory experiments on animals, they increase the predisposition to infectious diseases by diminishing the resistance (Kober and Hayhurst). Rival has noted a case of pulmonary gangrene. Typical paroxysms of a fever called "bone fever" have been reported among workmen handling bones.

Gases and poisonous fumes given off during the various operations cause disorders with symptoms appropriate to the products concerned.
Dusts particularly exert their mechanical or chemical action on the ocular and respiratory mucous membranes. Cases of perforation of the nasal septum and irritation of the respiratory passages have been noted by Borntraeger, Enderlen, Heinzelerling, Lewin, Mayer, Oliver, Roth, Villaret and Wallsdorff.

For respiratory pathology see the articles already quoted ("Basic Slag", "Calcium Cyanamid", etc.).

As regards the eyes, sulphate of potassium causes superficial lesions of the cornea; the nitrate and superphosphates are much more dangerous on account of the presence of phosphoric acid and phosphoric anhydride, which exert a caustic effect on the cornea. Augstein, the elder, has studied diseases of the eye caused by manures, including oedema of the eyelids, opacity of the cornea, and partial necrosis of the conjunctiva with perforation and protrusion of the iris. Serious lesions of the eye from manures have been observed by Hessberg and Schmidt-Rimpler. These lesions almost always consisted of keratitis; it was only in Blondi's cases that blepharitis occurred with oedema of the eyelids. According to Schmidt-Rimpler, it is rare to find keratohypopyon, because artificial manures exercise a chemical action without the intervention of pathogenic agents. These last on the contrary intervene when manures of animal origin are concerned. Antonelli in 1909 described a typical clinical picture among the agricultural workers of Latium using dung. It comprised palpebral vibrio gangrene with very striking general symptoms, palpbral oedema, high fever, and delirium. The gangrene is confined to the affected eyelid and heals by lysis in eight to ten days without affecting the eye.

But the most important troubles are the cases of dermatitis, characterised sometimes by a thinning of the epidermis, laying the dermal papillae almost bare, sometimes by an acute erythema, or eczema which extends to the destruction of the epidermis with serious eating into and necrosis of the skin. Several fatal cases with secondary septicaemia have been reported. Manipulation of such phosphatic manures as Thomas slag and superphosphates dries the skin, rendering it hard and cracked. Nitrate of ammonia, Chile saltpeter and kainite have the same effect though weaker. Still more serious lesions have been observed, for example ulceration of the genitals or cancer of the testicle among workmen handling guano. The use of manures creates risks which are dealt with in the articles "Agricultural Labourers", "Basic Slag", etc.

Hygiene

Animal manure works come within the category of dangerous trades on account of the nauseating smells which they emit. For hygienic purposes measures are taken to keep such works at some distance from dwellings; to enclose the work places or the walls; for paving of the yard of the works so as to render ground impermeable; to keep shut openings on to the public road; for storing solid or liquid materials in impermeable tanks or ground; for effective ventilation of store places, and prohibition of handling the products there; and for the treatment of materials as soon as they arrive at the works, carrying out the mixing under covered outhouses, the floor of which must be impermeable. In that case materials must be deodorised by chemical products. All parts of the factory must be kept in a constant state of cleanliness. Accumulation of filth and excrement must be prohibited. Yards or sheds or casks or carts used for the transport of raw materials or manufactured products must be frequently washed with chlorine water or formalin. Waste water and washings, after certain preliminary treatments, chiefly for the removal of the fats, if necessary, must be discharged by a drain to the sewer. The removal of night soil over long distances must be prohibited.

Hand work must be replaced as far as possible by mechanical or automatic methods. Liquid manures should be poured by suction or pressure. Operations giving off injurious products should be carried out in closed apparatus, or, if that is not possible, in apparatus with efficient localised exhaust. In the case of sulphurous or hydrofluoric gas, or vapours given off during the cooking of certain animal products, recourse must be had to condensation (air or water), to combustion, or to treatment by such chemical products as active charcoal and chlorine. All dusty operations should be carried out in closed apparatus, or, in the case of packing into bags or barrels, under efficient exhaust. Measures must be taken against risks of fire and explosions; and to ensure personal cleanliness by the provision of masks, goggles, respiratory apparatus, working clothes, leggings, sabots, lavatories and douche-baths.

For prophylaxis against vibrio...
gangrene Antonelli advises the use of goggles protecting the cheek bones and brows. Protection must be taken against flies. Itching must be resisted and the face must not be scratched; all soiling of the face by dung must be carefully wiped off by a fellow workman; rigorous personal cleanliness of the hands, face and hair must be ensured.

During the use of manure the scattering of it by hand must be prohibited. Recommendations may also be made to work with the wind behind, and to avoid putting hands which have been soiled by manure to the eyes.

**Legislation**

As regards manures of animal origin the Argentine laws exclude women from depots of manure, rags, bones and animal waste; the French law, from depots, as well as from the handling of manures. In Canada (Quebec) boys under sixteen years are excluded from manure works and depots; boys under sixteen years and women under twenty-one years are excluded in Spain from manure works and depots. As regards chemical manures see also the corresponding articles ("Superphosphates" etc.). In Argentina women are excluded from the parts of works where fumes are given off in consequence of acids; in Greece, boys under sixteen years and women of less than twenty-one years when the escape of dust is not provided for by mechanical means; in Italy, boys under fifteen years and women under twenty-one years are excluded in Spain from manure works and depots.

File-cutting may be done by hand or mechanically. In hand cutting the anvil is furnished with a kind of metal bed which is as soft as possible in order not to damage either surface of the file during the successive operations.

This support or bed, called a "die" was formerly solely made of soft lead. At present for the manufacture of special files which demand a lead support, hard lead or lead with a considerable antimony content is used. The majority of large establishments have, however, replaced these lead supports by supports made of zinc. An alloy of tin (70 per cent.) and zinc (30 per cent.) has been used with good results in Russia (Gladstein and Duschak).

With a hammer of a special form, the weight of which varies in accordance with the size of the file from 1 to 6 kg., the file-cutter gives 150-200 blows per minute on a small triangular graving tool which he holds in his left hand. In consequence of the specially shaped handle of the hammer, the file-cutter is greatly aided by the elastic rebound of the hammer which considerably facilitates his task. Similarly, after each blow the graving tool jumps from its place. The skill of the worker consists in rapidly bringing the outer edge of the graving tool opposite the groove formed by the preceding blow on the file before executing the following blow.

In mechanical cutting the file is automatically displaced on its support after each blow from the graving tool. The worker has only to regulate the violence of the blows, which should increase in a constant manner from the point of the file to its extremity.

Files after being furnished with grooves are passed on to a hardening process. In small establishments they are exposed to heat in an annealing furnace with open flame after having been coated with a plastic mixture composed of kitchen salt, powdered carbon, ammonium chloride and potassium cyanide (Derdack). The exact consistency of this mixture is however kept secret by the establishments, tradition here playing an important role. Welsbach visited a small estab-
In larger establishments hardening of files is effected in baths of lead or of salt. After hardening and annealing, the file is cleaned by means of sand spray or by steam. The rasp-cutter, by means of a graving tool, raises asperities on the surface of rasps or graters. The files after cleaning arrive at the warehouse for classification, packing and export. Files in wood, horn, bone, etc., instead of grooves have asperities raised by means of a punch and known as grains d'orge (grains of barley).

Dust formed by file-cutting, during which the worker is obliged to assume a bent position.

The results of enquiries recently undertaken by German experts are not in agreement. In fact analyses of the air carried out by Weisbach have brought to light the presence of 10-20 mg. and near the points of dust formation of 15 to 30 mg. of dust per cubic metre. Five analyses of dust samples, however, effected by current analytical methods were not found by him to have revealed the presence of lead. In using the Trillat method, he however found on two occasions traces of lead.

Fig. 101. — Interior of a file-cutting establishment.

**Sources of Risk**

Whilst there have been reported, according to Derdack, cases of poisoning by hydrocyanic acid, medical literature has for long contained references to the important danger of lead poisoning to which file-cutters are exposed. In large establishments danger from the hardening bath is not very important, the use of lead vats not being permitted unless these are provided with effective exhaust ducts. In hand work, on the contrary, when lead supports are used there come into consideration the intimate contact of the left hand with the support as well as inhalation of lead bearing though after colorimetric estimations the amounts in question only gave values inferior to 1/100 mg. per cubic metre. According to Weisbach, these results, quite negative from a practical point of view, as regards the possibility of lead dust inhalation, are said to correspond to the results of blood tests carried out by this expert amongst file-cutters in the establishments in question. On the other hand, suspect or even positive results have been reported by P. Schmidt (punctate basophilca over 100 per million).

According to Weisbach, the negative results relative to the inhalation of lead dust go to prove the possibility of effective protection against lead
absorption, granted goodwill to do this and proper instruction of the worker from his apprenticeship onwards.

Fig. 102. File-grinder in typical working attitude.

Fig. 103. Grinding of semi-chisel files.

 statistics

Weishach is of opinion that there occurred formerly numerous errors in diagnosis which resulted in various troubles of diverse origin encountered amongst file-cutters being ascribed to the action of lead.

In other countries however the morbidity and mortality rates for file-cutters due to lead poisoning are fairly high, especially in the small workshops, though, apart from the inhalation of lead dust, there are many causes which contribute to this state of affairs: lack of cleanliness amongst the workers who do not wash before meals and, on the other hand, conditions in close and badly ventilated workshops where the workers in question are engaged. The file-cutter and especially the polisher exercises a very tiring trade, for he works in a very uncomfortable position bent forward with his feet in a fixed position and his chest and abdomen compressed. His trade, which demands a constant effort, exposes him to injuries, and particularly to eye strain, where it is a question of making fine files. There must also be taken into account the fact that the worker is constantly exposed to the risk of soiling his skin and clothing with lead, and that workers working with wet grindstones are liable to contract rheumatical affections as their clothes are completely soaked. On the other hand, work at the hardening furnaces with a naked flame exposes the workers to the harmful action of heat, smoke and gas.

There have been reported cases of poisoning by carbon monoxide as a result of bad withdrawal of smoke from the forge.

statistics

Without going into details as regards to the somewhat out-of-date statistics collected by the Leipzig Sickness Fund, it may be recalled that in returns for 1913 an average of 5.25 per cent. of the file-cutters of Berlin using a lead support were attacked annually by lead poisoning. Köpfke, according to Spremeyer, in the German Factory Inspectors' Reports for the period 1930-1937, there are mentioned several cases of paralysis of the hand with atrophy of the thenar muscles.

In Great Britain out of 100 file-cutters, thirty-seven years of age on an average, and having an average length of employment of twenty-three and a half years, there were found 74 with a Burton line, 28 having suffered from colic and 20 affected with paralysis of the muscles of the forearm. Sinclair White, 1902. Conditions were then certainly less favourable than they are today. Thus, for example, in 1899 cases of lead poisoning notified amongst file-cutters reached a total of 41
(with 1 fatal case), whilst the annual average for the period 1900-1909 was 21.1 (1.9 fatal) and for the period 1910-1918, 9.0 (0.44). In 1919 no case was notified: in 1920 three cases, one of which was fatal. From this year onwards separate statistics are no longer given for file-cutters.

According to the English mortality statistics (1921-1923), amongst forty-four occupations classified in increasing order of mortality, file-cutters occupy the fortieth place. The comparative mortality figure (England and Wales) for all other causes of disease amongst file-cutters exceeds the average by 85 per cent, and is only exceeded by that for four other occupations. However, in proportion to the earlier statistics (1910-1912) there has been a decrease, since the excess at this period was 91 per cent.

The comparative mortality figure per 1,000 due to certain causes for all occupied and retired persons aged from twenty to sixty-five and that for the category of file-cutters showed the following figures: all causes 1,851 (1,000); tuberculosis 426.8 (177.3); cerebral haemorrhage 120.0 (44.9); diseases of the respiratory system 306.9 (151.7); diseases of the circulatory system 207.5 (152.2); chronic nephritis 215.0 (34.5).

Taken in its entirety, the mortality is at least double that of the average for most of the causes, whilst for chronic nephritis it represents six times the average mortality. It was ascertained that there were no deaths due to lead poisoning though the frequent incidence of nephritis and cerebral haemorrhage suggest the action of lead recognised in the past.

**Pathology**

The industry of file-cutting is still at the present time indicated in manuals on occupational pathology as one of the most unhealthy trades. This is due to the fact that the use of the lead support is still fairly extensive and it is necessary to insist on the substitution of hard lead, or still better of an alloy of tin and zinc. In this way one of the principal sources of risk may be eliminated.

Enquiries revealed the fact that a large number of file-cutters commenced work at the age of fourteen and that they were mostly married men with a normal number of children. There are found especially amongst file-cutters engaged in cutting files by hand, individuals still following their occupation at seventy years of age, and having completed forty, forty-five, fifty-three, fifty-five and even fifty-six years of employment (Weisbach).

Pathology in regard to these workers is chiefly concerned with lead poisoning. Legge quotes for the period 1913-1914 an annual average of ten cases per thousand occupied workers (there were at this period in employment 5,550 file-cutters). The cases reported during the period 1900-1909 were distributed as follows: 174 cases amongst
the men and 34 for the women: 48.9 per cent. of the men and 23.5 of the women were affected to a serious degree; 28.2 per cent. of the men and 70.6 per cent. of the women were affected by lead poisoning for the first time; and 22.4 per cent. of the men and 11.8 of the women for the second time. As regards the form of the disease, Legge provides the following percentages: gastritis 59.8 per cent. of the men and 67.7 per cent. of the women; anaemia 28.7 per cent. of the men and 50.0 per cent. of the women; paresia 46.0 of the men and 8.8 of the women; encephalopathy 4 per cent. of the men; rheumatism 9.2 per cent. of the men; headache 8.6 per cent. of the men and 5.9 of the women; various forms 11.5 per cent. of the men and 5.8 of the women.

Legge and Goadby have drawn attention to the fact that file-cutters only show obvious symptoms of lead poisoning after a long period of employment. These experts, however, report the very slow and insidious evolution of the poisoning, which is marked at the outset by organic degeneration accompanied by muscular atrophy (thenar and hypothenar, lumbrical and intersosseous of muscles of the hand), chronic nephritis, and, in particular, a form of pulmonary tuberculosis showing a very high rate. Legge and Goadby have also revealed the fact that though the number of victims of lead poisoning may not be as high as in the case of other categories of workers, the cases which do occur are, how-

ever, characterised by the peculiar severity of the attacks.

In 1913, Teleky described a type of paralysis and atrophy of the muscles of the thumb, which he attributed in part to lead poisoning and in part to pressure of the hammer. In 1926 Walkoff, having met with two cases of this type of paralysis amongst file-cutters using supports made of pure tin, concluded that the paralysis could not be traced to the influence of lead which besides was not present in the dust produced in the workers' neighbourhood, but that the condition should, on the other hand, be attributed to strain due to the effort necessary for holding the graving tool. It remains, however, to be seen whether the cases in question were not former victims of lead poisoning.

There have been described as affecting file-cutters occupational stigmata consisting of the formation of horny areas situated chiefly on the soft surface of the little finger of the right hand and clearly restricted to the inner side of the finger (Chajes), and also of incrustations of the nails from iron or copper filings (Heller). The reduced resistance of file-cutters to disease may be in some degree attributed to excessive consumption of alcohol which, however, is only true of conditions in the past. At the present time, in fact, the workers have been obliged to abandon this habit at least during working hours, since they themselves have come to recognise that

Fig. 105. — File-cutting machines.
under the influence of alcohol a file-cutter doing hand work, for instance, cannot compete with machine work as regards quality and quantity. Similarly, workers engaged on machine file-cutting have recognised that, under the influence of alcohol, they were unable to guarantee regular working of the machinery, with the result that the product obtained became very much inferior to that produced by hand work. Finally, the increased price of alcohol has also played a part in diminishing the former excessive consumption traditional in this occupation.

**HYGIENE**

All hygienic measures relative to work involving manipulation of lead should, of course, be applied in the file-cutting industry (see article "Lead"). The English Regulations No. 507 of 1903 require, for instance, that in workrooms where file-cutting is done by hand, each bench should have a cubic air space of at least 11 metres. There must not be taken into account in this calculation that part of the workroom which is 3 metres above the ground. Each bench should be separated by at least 90 centimetres from the neighbouring bench. The flooring of the workroom should be uniform, solid and impermeable, and such that it may be cleaned by the damp method at least once a week. The walls and ceiling should be limewashed unless they are varnished or enamelled. A thorough cleaning by the damp method is compulsory once every six months. The workers should be provided with an apron covering them to the knees, and should have adequate facilities for assuring personal hygiene (wash basins, etc.). File-cutting is prohibited in rooms used for sleeping accommodation or for meals.

Localised ventilation for the removal of the dust with a lead content has never been demanded since the workrooms in question are generally not supplied with power. That the number of cases of lead poisoning has diminished in a remarkable degree is certainly due to the introduction of mechanical methods and to the more and more extensive use of supports containing very little lead (in Great Britain a lead content inferior to 5 per cent. is required) or made of zinc or a tin alloy. As regards the coating product with a cyanide of potassium, the cyanide of potassium to be kept in hermetically sealed recipients and the preparation of the mixture only to be entrusted to a competent person specially designed for the purpose.

Coating of the files to be done on a support which permits of easy cleansing.

Strict cleanliness of the flooring in front of the drying stove as well as of the place in which the files are stored after being coated.

Washing accommodation sufficiently plentiful, together with provision of soap, towels, etc., in the immediate neighbourhood of the working posts.

Special working clothes (overalls) for workers engaged in coating files, these clothes to remain always in the factory and to be cleaned periodically.

Before addition of potassium cyanide, the hardening mixture should not have an acid reaction in order that there may be no evolution of hydro-cyanic acid.

The staff engaged in this work to be instructed as to the toxic properties of potassium cyanide.

Particular attention to be paid to the necessity for training apprentices and inculcating habits of personal hygiene and careful practice in regard to clothing, as well as the maintenance in a cleanly condition of workrooms which should be well-lighted and well-ventilated.

In small undertakings, which are still numerous, and which are usually engaged in renewing old files, and in which it is difficult to rely on the observance of strict measures of hygiene, there should be required periodical medical examination of the workers with a view to discovering early symptoms of lead poisoning.

Careful supervision of workers showing symptoms of lead absorption and likelihood of developing poisoning.

**LEGISLATION**

Special regulations relative to the protection of the health of file-cutters have been issued in Germany and in Great Britain.

In **Germany** the Minister for the Interior published in 1907 a cautionary poster intended for use in file-cutting establishments of the Empire. The same year the Minister of Commerce and Industry in
Prussia issued an Order, accompanied by a cautionary poster, containing instructions in regard to lead poisoning for file-cutters. Finally, in Saxony, at the same time, an Order was issued relative to the exhibition of the poster published by the Federal Government.

In Great Britain, Regulations No. 507 of 19 June 1903, issued by the Home Office, provide for the application of hygienic measures in workshops where file-cutting is done by hand. A poster "Form 915" has been issued for exhibition in factories where file-cutting is effected by hand.

Compensation for lead poisoning is provided by legislation under the conditions detailed in the articles "Lead" and "Occupational Diseases: Compensation".

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The plates (figs. 101-105) have been prepared from photographs provided by the author and published with the permission of Messrs. J. Springer, Publishers, Berlin.

Dr. W. Weisbach (Dresden)

Fire-Lighters (Rosin)

These fire-lighters are prepared from hard or liquid pitch. The hygienic precautions vary according to the materials employed.

The construction of workrooms should be of fireproof material. The most important precautions against risk of fire may be mentioned: the provision of metallic covers for the boiler used in melting the resin. These covers should be provided with hinged and placed under ventilation hoods connected with chimneys for removal of the gases from combustion. A quantity of loose sand and a shovel should always be provided near the boiler. Any wooden beams in the workshop should be coated with plaster, the power machine should not be placed in the principal workroom, and transmission gears should be away from the surrounding walls. No flaming lights should be allowed, and ventilation should be effective and provided by a well in the ceiling with Venetian blinds. Electric lighting should be used, and the introduction into the workshop of naked lights should be forbidden, and likewise smoking. The sawdust and wood debris which accumulates should be removed daily, and this latter should not be used for heating the machines, into which combustible material should be fed from outside. A good system of appliances for dealing with outbreaks of fire should be provided.

Gas and fumes should be neutralised by fire. Waste water should be purified, especially when it contains tar as well as any tar residues. All effective measures should be taken against the raising of dust and the liberation of irritant emanations, especially during crushing and pulverising of resinous materials.

For fire-lighters prepared from hard pitch the same precautions are necessary, and care should be taken to avoid the mixing of hard pitch with liquid pitch or other fluid matter likely to give off disagreeable emanations in the course of manipulation.

Dr. W. Weisbach


Amongst injuries to which firemen are exposed there may be quoted as of first importance lesions and injuries of a mechanical order which occur when the alarm is given or at the place where the fire has broken out. The particular conditions under which firemen must carry out their work explains to some extent the incidence of such accidents, measures of prevention and safety such as it is possible to adopt in workshops being quite out of the question during disasters of the kind in question. The conditions are characterised by disorder and confusion, and the firemen are obliged to be in the midst of the danger, very often in darkness, surrounded by flames and smoke, or on scaffolding temporarily erected, and with the additional risk due to explosions, buildings falling in, etc. Since the war it appears that the number of accidents and
wounds amongst firemen has diminished, and this may be due to the fact that efforts have been made to improve as far as possible the conditions under which extinction of fires takes place: use of anti-gas masks, installation of lighting and reflectors doing away with the necessity of working in darkness, substitution of motor traction for horses, etc. Whilst the number of burns, varying in severity, is fairly restricted, the most important risk to which the firemen are exposed is "poisoning by fumes", a mixture of gas, fumes and smoke given off from the combustion of wooden articles: furniture, planks, materials, papers, straw, etc. Where combustion is complete the gases in question generally are carbon dioxide, nitric acid, nitrous acid, ammonia, and very often sulphur dioxide, but where it is incomplete there is added to these carbon monoxide, the toxicity of which is well known, various hydrocarbons, formaldehyde, formic acid and quantities of other gases and fumes: compounds of phenol, methyl alcohol, aceton, acetic acid, etc. (Leppmann). Amongst the fumes it is chiefly those which contain carbonic acid compounds, given off, for instance, during combustion of material impregnated with pitch, which are particularly dangerous. Poisoning by fumes is much more serious when it is a case of fumes and gases given off in enclosed spaces or in rooms where the air inlet is insufficient. Such poisoning is usually manifested by affections of the circulatory system (Coullaud); very varied forms have, however, been noted as occurring amongst firemen. Thus in Dresden and in Berlin there has been observed a predominance of nervous affections, at Copenhagen of particular symptoms affecting vision, at Frankfurt cardiaque troubles, etc. It is important to note that the evolution of the poisoning is not in proportion to the severity of the initial symptoms, but rather related to the constitution and individual resistance capacity against the effect of different poisons. Very often these smoke, fumes and gases cause a diminished resistance of the system and favour secondary infections or the outbreak of a disease already present in a latent state. In certain cases symptoms of poisoning only appear a few days later, after a latent period.

In general there is irritation of the respiratory passages or the mucous of the nose and especially of the ocular conjunctiva. These troubles are accentuated by the concomitant action of heat and dust, which at a very high temperature may in themselves cause intense irritation of the mucous membrane.

The danger of poisoning is considerable as soon as when fire extends to chemical products likely to give rise during combustion to toxic gases. This was notably the case during the fire in the Schering chemical products factory (1897), where three officers and 37 firemen suffered from poisoning from fumes, which was serious in 20 cases (10 firemen had to leave the service on account of invalidity, and there was besides one fatal case). In another fire (1916), where the explosion of 25 carboys of crude nitric acid were overlooked in the smoke, all the firemen engaged in extinguishing the fire were poisoned by nitrous gas (11 persons affected, with one death and 6 serious cases; one of these cases five years afterwards presented bronchial dilatation with haemoptysis). Recently fires or escapes have led to poisoning by phosgene (nitrous oxide), nitrous gas (celluloid factory), ammonia, methyl chloride, etc.

In certain cases of poisoning due to fumes there are noted either nervous troubles productive of mental confusion or cardiac troubles (there has, for instance, been described a case of nervous cardiac weakness).

Digestive troubles are frequent and their outbreak is favoured by irregularity and sudden interruption of meals. While extinguishing fires firemen suffer from violent thirst, leading to the consumption of cold drinks, which forms a further cause of weakening of the digestive organs.

Exposure to inclement weather and especially sudden change from cold to heat given off during the fire, and *vice versa*, favour attacks of cold and respiratory affections: congestion of the larynx and bronchial tubes, tonsilitis, pneumonia, muscular and articulor rheumatism, etc. Nervous troubles are all the more easily induced since poisoning has left the nervous system in a state of very slight resistance to infection. Finally, there should be noted amongst firemen the frequent occurrence of arteriosclerosis, anaemia and ocular symptoms. In the latter case it is a question of mechanical lesions, of foreign bodies in the eye, of conjunctivitis, and at times of alteration of the cornea and crystalline lens.

**Statistics**

Statistics in regard to the occupational diseases of firemen are not very numer-
by reason of the fact that the number of persons regularly engaged in this occupation is not very high. Older statistics relate to Berlin firemen and go back to the period comprised between 1891 and 1900 (Leu) and give the following figures: mechanical lesions, 943; digestive troubles, 812; general diseases, 811; diseases of the locomotory system, 527; diseases of the respiratory system, 497; diseases of the skin, 335; diseases of the nervous system, 270; diseases of the eyes, 150; diseases of the circulatory system, 84; diseases of the genital-urinary system, 42; etc.

In the same town for the period 1912-1919, for an average annual figure of 191 firemen, the situation was as follows (Chajes):

<table>
<thead>
<tr>
<th>Diseases</th>
<th>Number of cases per 100 firemen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1912</td>
</tr>
<tr>
<td>Mechanical lesions</td>
<td>157</td>
</tr>
<tr>
<td>Digestive troubles</td>
<td>192</td>
</tr>
<tr>
<td>General diseases</td>
<td>176</td>
</tr>
<tr>
<td>Diseases of the locomotory system</td>
<td>139</td>
</tr>
<tr>
<td>Respiratory diseases</td>
<td>50</td>
</tr>
</tbody>
</table>

Finally, for the period 1920-1924, the following figures indicate the incidence of mechanical lesions amongst Berlin firemen (Chajes):

<table>
<thead>
<tr>
<th>Number of fire stations</th>
<th>1920</th>
<th>1921</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of firemen</td>
<td>3,171</td>
<td>4,506</td>
</tr>
<tr>
<td>Lesions</td>
<td>288=9.1%</td>
<td>317=7.8%</td>
</tr>
</tbody>
</table>

In general it is a case of wounds, contusions, dislocations, fractures and burns. As regards mechanical lesions, for the town of Munich the figures for the period 1921-1925 were as follows: 6.6, 10.2, 10.2, 7.9, 12.8 per cent. of the total number employed, and 13.8, 16.1, 16.8, 9.7, 19.8 per cent. of the total number of diseases.

It would appear that it is necessary to regard these tables as being rather below what occurs in reality since a good number of lesions and wounds of secondary importance have been classed amongst "slight affections". Similarly, the number of days of sickness amongst firemen appears to be somewhat inferior to the number of days of sickness for other occupations. On the other hand, the number of cases of diseases met with amongst them is rather higher. Expressed in figures the situation as regards firemen is as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of fire stations</th>
<th>Total number employed</th>
<th>Cases of sickness</th>
<th>Per 100 persons employed</th>
<th>Days of sickness Total</th>
<th>Per case</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920</td>
<td>40</td>
<td>5,007</td>
<td>3,862</td>
<td>77.6</td>
<td>56,915</td>
<td>14.7</td>
</tr>
<tr>
<td>1921</td>
<td>40</td>
<td>5,011</td>
<td>3,772</td>
<td>75.3</td>
<td>58,672</td>
<td>15.5</td>
</tr>
<tr>
<td>1922</td>
<td>40</td>
<td>5,360</td>
<td>4,091</td>
<td>92.3</td>
<td>62,276</td>
<td>12.7</td>
</tr>
<tr>
<td>1923</td>
<td>40</td>
<td>5,257</td>
<td>3,813</td>
<td>72.5</td>
<td>50,719</td>
<td>13.8</td>
</tr>
<tr>
<td>1924</td>
<td>47</td>
<td>4,303</td>
<td>3,171</td>
<td>79.8</td>
<td>51,430</td>
<td>16.8</td>
</tr>
</tbody>
</table>

For all occupations (according to the Sickness Fund statistics of Germany) the number of cases and days of sickness per total number of insured members is represented by the following figures:

1922: 47.9 cases of sickness with 23.7 days of sickness per case; 1923: 32.4 cases of sickness with 34.4 days of sickness per case.

As regards burns, it has been noted that
they are incomparably more rare amongst firemen than amongst private individuals. Thus for the period 1909-1913 out of 1,222 cases of diseases occurring amongst firemen, 15 only were due to burns.

According to Freund, chief of the Hygiene Service of Vienna, there occurred in the course of the period 1909-1925 amongst the regular staff of the fire brigades of this town, 11 to 12 burns per 100 wounds. Though the number of times which the fire brigade of the town of Vienna was called out had been high — 1,722 times in 1913, comprising 912 fires and 6 explosions — there was only reported for the period 1909-1913, as affecting a staff of 638 men, 45 cases of burns, including caustication, with incapacity of 185 days and hospital treatment in 12 cases.

During the second half of this period there only occurred 15 cases, involving 221 days of sickness and 21 days of hospital treatment.

HYGIENE

Specially high incidence of accidents and diseases amongst firemen is, as has already been said, inherent to the nature of their occupation. It is, nevertheless, possible to improve the existing situation by adequate means; in the first place by judicious selection of those who desire to enrol as firemen. Quite recently particular attention has been bestowed on this matter and research has, for instance, been instituted at Munich (Schmich) in the course of which candidates are subjected to personal and collective tests calculated to bring to light the requisite aptitude and certain defects which constitute a counter-indication to enrolment; at Moscow research has been undertaken with a view to studying the psycho-physiological conditions under which the work in question takes place (Levysz, Nitsch, Netzki and Retlingberg); at Riga candidates have been subjected to a psycho-technical examination in the laboratory of the municipal institute for the young (Drill), etc.

Nevertheless, however rigorous may be the entrance examination, it is not sufficient unless completed by subsequent periodic examinations revealing the state of health of firemen who have been exposed to the various risks of their occupation. Here it is a question especially of examination of the nervous, respiratory, circulatory and digestive functions.

Among the causes which may be considered as predisposing those in question to accidents there must be taken into account fatigue and the irregular nature of the life which they are forced to lead. The period during which a firemen is on duty is often 24 hours, implying remaining under tension for this length of time with exposure to the greatest dangers (Chajes). The exhaustion involved is revealed by the fact that a considerable number of firemen are pensioned off at an age when other workers are still fit to carry on their occupations.

An improvement of this state of things may be obtained by introducing shorter working hours. An experiment of this kind instituted for instance in Munich has proved that the shift system with rest periods has diminished the number of illnesses by about 40 per cent.

On the other hand, the fireman himself must be brought to recognise the capital importance of personal hygiene which he must observe wherever possible: asbestos screens as a protection against heat, smoke hoods, complete protective equipment against fire with provision where necessary of apparatus for water spraying, steel pipes of the Swift type with a water curtain, in fact all devices facilitating fire entry to the flames by firemen. Generally firemen use leather gloves as a means of protection and asbestos capes with a closing made of mica which can be drawn over the head, leather jackets descending to the hips, helmets which can easily be turned round so that the leather flap covering the back of the neck may be drawn over the face, screens or wet cloth, etc.

Every section of a fire brigade should be provided with first-aid apparatus in a sufficient number and kept in perfect working condition. In addition measures to be taken with a view to the prevention of accidents should be well known to each firemen and practical demonstration of these should, as far as possible, be engaged in during training, in order that they may be usefully applied not only for the firemen, attention should be drawn to the duration of working capacity wherever it is a question of firemen. In view of the danger which characterises the work in question and the considerable exhaustion of the system involved thereby it only seems right that the pensions for these workers should be calculated on a period of service plus an augmentation of 50 per cent. (Chajes).

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First Aid

The organisation of medical first aid to be given to victims of industrial accidents is based on a few principles, which it is not without utility to recall here:

I. The more or less rapid progress of healing in the case of wounds depends almost always on the efficacy of first-aid measures applied. That is a truth recognised by all doctors engaged in factory surgery.

II. Infection of wounds is not immediate. It may be stated that at least for the first six hours following an injury there are only found in the tissues saprophyte microbes of little virulence and hardly any infectious microbes. Even after the twelfth hour, and often still later, it is easy for a trained surgeon, applying active and energetic methods, to obtain healing by first intention in simple wounds and at least to avoid serious secondary infections even in the case of considerable destruction.

III. Many wounds have become infected in consequence of a first dressing applied on the spot having an aseptic appearance or constituting a defective antiseptic.

IV. All wounds, even those of slightest importance, require to be dressed at a well-equipped medical centre and by, or at least under the control of, a surgeon trained in the treatment of industrial accidents.

From the fulfilment of these principles may be established rules to direct the application of precautionary methods to be adopted and also those rules which require to be followed after the occurrence of accidents.

Preventive Methods

The ideal plan is to create, so to speak, on the spot of the accident, a first-aid centre generously organised and fulfilling all the surgical requirements likely to occur. This ideal cannot be realised unless the installation is itself perfect, that is to say, unless it unites with the ordinary conditions for scientific hospital treatment a complete surgical equipment at the disposal of expert surgeons and available at all times. This ideal has already been realised in the case of large and wealthy industrial establishments in the interest of workers in the factories and workshops. It has also been put into practice successfully by groups of adjacent establishments where workers are exposed to similar risks, and it is also a principle which has animated certain insurance organisations and led them to create treatment centres exclusively at the service of their members.

It must be recognised that installations of the kind above described are, however, relatively rare. They might be much more numerous if heads of industrial establishments of a less individualist type would only take steps more frequently to enter into a common agreement for the establishment of such important centres of treatment. It would constitute besides for them, as it has done in the past for others who have followed this method, not financial loss but, on the contrary, a means of reducing considerable loss caused by accident compensation.

It is none the less true, however, that at the present time, for the large majority of establishments of average and small size, other means of medical assistance must be relied on. In the case of this type of establishment, public hospitals and private clinics may fulfil to some extent the same requirements, on condition that they are adapted to this type of work, which is somewhat special in character, that is to say, that besides adequate means of treatment they possess the further possibilities of telephonic communication, of suitable motor vehicles for transport, available at all times.

In the majority of industrial countries the accident insurance laws
have already, for some years back, made it compulsory for the heads of establishments to assure for each member of their staff seized with sudden serious illness or the victim of an accident (whether occupational or otherwise) medical first aid and comfortable transport to the nearest first-aid station. Further, in these countries the system of agreement between industrial employers and medical surgical institutions has received considerable development. Regulations in certain countries require that every establishment of any importance should provide a first-aid station (with expensive equipment) or should furnish proof of an agreement with an institution capable of discharging its legal responsibility in this connection and adequately organised from a medical point of view. Under certain legislation such institutions are, for instance, under the control of the factory medical service (Belgium), and are not accepted unless they fulfill the requirements demanded.

Thus, for example, in Belgium the network formed by institutions of this kind is sufficiently close to ensure that no part of the country is situated at a distance further away from one or other of these than 25 kilometres (maximum allowed by the law). This obviously constitutes favourable circumstances, explained by the density of the population, and which it would not be possible to realise everywhere. It may be said, however, that the transport of a seriously wounded patient for even double the distance in question does not imply really grave inconvenience, provided the requisite precautions for such transport have been carefully adopted.

It is besides beyond doubt that still further measures are necessary in most cases to assure to the victim of a serious type of accident the best chance of rapid recovery. Victims of serious accidents should be spared the pain, the danger and the agony to which they may be subject in awaiting more effective treatment by a surgeon. It is further essential that in cases of complications such as asphyxia or electrocution, which are a direct menace to life, it should be possible to provide on the spot the treatment of which the victim stands in urgent need. It is necessary, therefore, that in all establishments there should be certain means of temporary first aid, together with the presence of trained persons in order to provide adequate first aid.

According to Glibert and Stassen, it may be said in regard to temporary first-aid treatment that as to material means these are not very complicated and are of easy realisation in the great majority of cases; a reservation being of necessity made, however, in relation to certain particular circumstances such as those connected with extensive underground work at great depth, work in compressed air, carting in thinly populated areas, transport by sea, etc. The means in question are restricted to the possibility of sheltering the victim rapidly and comfortably from inclemency of the weather, of keeping him warm or at least of combating the very dangerous effects of chill, and of providing
wholesome drink, since a sensation of thirst is general after major injuries.

The temporary shelter in question may not necessarily be a special place exclusively reserved for medical treatment. In many cases, on the contrary, small factory sick rooms are places but little adapted for the care of a severely injured person. When they are not used daily, they are rarely maintained with sufficient care and foresight to be instantly adapted to the function which they are intended to fulfil. Experience has shown that, on the occasion of an unexpected visit by factory inspectors, such places were for the most part neither heated nor ventilated, and that the condition of their maintenance left much to be desired. In numerous cases they have been found to be in a state of decay and encumbered with various objects having no relation to the treatment of the sick or wounded. Where, on the contrary, it is a question of a sick room in daily use, surgical cleanliness is more than ever necessary, since the danger of infection is increased by reason of the treatment of infected wounds and sometimes even of serious infectious diseases.

It is easier and sometimes preferable to transport the victim of an accident temporarily to a quiet spot usually inhabited which ensures heating during the cold season and means that it is fairly well kept. Such a place might be an inhabited room or office, or even an annex to a warehouse as is found in a number of establishments. In open-air yards, a clerk's office or tradesmen's office, or even the caretaker's dwelling, usually fulfils this purpose, without great inconvenience for the patient. The only essential conditions to be required, and these must certainly be insisted on, are the following: it must be possible for the accident victim to lie down in a clean and healthy room sufficiently heated and sheltered from strong sunshine, protected from inclemency of the weather and from the presence of curious bystanders, and under the supervision of a person with some training. Even in out-door workplaces of a mobile and seasonal nature, such as in the building trade and in road-making, these conditions might be fulfilled and ought to be insisted on by all regulations on the subject.

The equipment requisite for first aid involves the possession of certain materials for dressings, and here there intervenes the very important question of the "first-aid box". Gilbert and Stassen are of opinion that when a surgical institution such as that described above is accessible, the first-aid box in the factory or yard may be reduced to almost nothing: some rolls of sterile dressing, two or three towels which may be used as Mayor slings, a box of strong safety pins and a woollen blanket. There may be added, if preferred, a small flask of strong vinegar of similar product intended for bathing the face.

In principle and excepting in cases involving sea transport or transport over great distances, which may be left out of account, Gilbert and Stassen consider that the first-aid box as generally conceived is a makeshift and that in cases where, in consequence of distance, it is necessary, it should be exclusively reserved for use by a doctor. In other cases and where it is not restricted to the above-mentioned items, they consider it more harm-
ful than useful. It incites the first-aid helper or even the doctor called in urgently to institute on the spot a more or less definitive treatment, which is always uncertain of result and too often the cause of secondary accidents of which the least that can be said is that they retard the truly effective intervention of the surgeon in cases requiring his attention.

The inspection of numerous first-aid boxes in factories has shown that the numerous products and varied instruments which most of them contain are either very useless or very out of date and impaired: the instruments are rusty, the rubber parts cracked, bottles of ether become empty by evaporation; in other cases corks become stuck in the necks of bottles, packets of cotton wool and gauze are opened and partly used, etc. In short, when at the end of six months or a year, the occasion for using these presents itself, the first-aid box has become unfit for use and offers in consequence the danger of creating a false security opposed to the adoption of the only really effective measures: rapid treatment at a well-organised surgical institution.

**First Aid**

The line of conduct to be followed in cases of accidents varies necessarily with the nature and gravity of the accident and with the circumstances in which it has occurred. It is, however, possible to indicate certain rules calculated to direct activity in all cases. The first thing to be done is obviously to remove the patient from the dangerous situation in which he is situated and place him in shelter as described above. In many cases this involves a fairly simple operation to anyone instructed in the manner of carrying a patient. In other circumstances, notably in the case of landslides in subterranean works, it may present particularly delicate technical difficulties and be accompanied by grave dangers. The study of rescue methods, however, does not enter into the scope of this article. It may merely be stated in passing that the first-aid worker should also have a course in rescue work and that the instructions to be given him in this sphere must often be very much more extensive than the activity called for in relation to the application of medical treatment properly so called.

Once the victim has arrived at a safe place, it is necessary first of all to abstain from all action likely to aggravate his condition or increase his sufferings. “Primum non nocere.” This is a rule the strict observation of which it is in general difficult to obtain, not only from the ordinary bystander but also from persons believing themselves sufficiently trained by reason of having followed an elementary course of Red Cross work or nursing. It is essential however, and very rare are

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**FIG. 108. — Schaeffer method.**

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drenched with blood no effort must be made to remove this clothing. If intervention occurs at the spot and moment of the accident, for the simplest methods: the clothing may be cut in order to uncover the wound and place a dressing on it. The best dressing is that which permits the first-aid worker to make a good dressing even with dirty hands. If several hours have passed before the victim has been able to be treated, and there is therefore the likelihood that haemorrhage has ceased so that in the torn clothing clots of blood and destroyed tissue form at the level of the wound a more or less consistent magma, precautions must be taken not to destroy what nature has already effected for commencing the healing process. There should be applied on top of the wound a dressing, which will prevent the wound coming in contact with new sources of soiling. The action of capital importance of the dressing is to warm the victim: blankets, hot water bottle, etc.

In other circumstances no effort should be made to ascertain whether the case is one of fracture, dislocation or a very painful simple contusion. To do so is wasted time. The limb should be put at rest by the simplest methods: a Mayor sling placed above the clothing, and the arm in flexion and the sleeve of the coat fixed to it by strong safety pins; sometimes even more simply, the arm supported by the hands and resting between two waistcoat buttons or in the opening of the shirt.

Where it is case of a leg wound, the victim should be placed lying down and the two legs placed one against the other. The healthy limb constitutes the best splint when the limbs are tied together without excessive constriction at the level of the knees and ankles with handkerchief, string, straps or other similar articles. In order to consolidate this temporary bandage there should be slipped carefully under the two attached members a towel or other piece of material, the rolled edges of which are applied on each side to the limbs. Some fresh bandages should then be attached to the knees and ankles, providing a mechanism of support which sufficiently immobilises the wounded limb to permit of transport.

It is easy to adapt these instances to the most diverse circumstances; they suffice to indicate the method to be followed, while taking into account the environment and the material at one’s disposal.

As regards transport to the stretcher or ambulance involving the minimum of pain, the following presents a very simple method of packing up: a seriously injured person. The opposite edge of a blanket are rolled towards each other very tightly. They then constitute two long cushions united by the centre of the blanket. The centre part, slipped under the patient and gently raised, constitutes a hammock the resistance of which is increased by the lateral rolls and permits of carrying the victim in a comfortable position. The victim, having been placed on the stretcher or the bed intended for him should be lightly and warmly covered by the unrolled edges of the blanket. This procedure is invaluable especially for removing wounded from places inaccessible to ordinary means of transport.

There remains to be dealt with the methods to be followed in the case of very severe haemorrhage, which persists despite compression of the wound by means of a dressing. Must a tourniquet be applied? If the doctor is present there must be left to his professional instinct the task of deciding what means of treatment will best suit the state of the victim: state of preparedness, digital compression of the artery in question, application of a mechanical method of hemostasis. Where there are only first-aid workers present, Gibert and Stassen are inclined distinctly to negative action in nearly all cases and this for the following reasons: the tourniquet applied for too long a period is a frequent cause of traumatic shock and gaseous gangrene. By stopping the circulation in the wounded limb it places the contused, destroyed and bruised tissues in the worst condition for resisting infection. In a crushed limb, which is cold and deprived of all circulation, there is produced, at the level of the destroyed muscular masses, phenomena of auto-

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**Fig. 106. — Howard method.**
ing the tourniquet leads to resorption of toxic products capable of producing in weakened and chilled subjects toxic shock. This, added to the traumatic and haemorrhagic shock, may constitute the coup de grâce which finishes the victim.

For a seriously wounded patient who has lost much blood and where the haemorrhage is, so to speak, arrested in consequence of lowering of the blood pressure (this is usually the case when the first-aid worker or doctor arrives), the experts in question have no hesitation in affirming that the tourniquet is more harmful than useful and that there is no necessity for employing it.

They believe that in the immense majority of cases of grave injuries resulting from wounds due to industrial accidents, the application of the tourniquet is not indicated and that local compression at the level of the wound by dressings is largely sufficient. One of these experts, in the surgical service under his direction in the coal mines, removed the tourniquet from his first-aid box five years ago and has seen arriving at his clinic, from places situated 15, 20 and even more than 30 kilometres distance, hundreds of cases of complex fracture of limbs due to crushing without ever having met with a case of death from haemorrhage during transport.

There are, however, circumstances where the application of a bandage tied at the upper end of the limb is urgently required. In these very rare cases it is advisable not to tighten the tourniquet unduly, and where the transport is long it is necessary from time to time to loosen the bandage in order to allow of the arrival of the blood, bearing its oxygen and its heat, to the chilled masses of muscle.

**ARTIFICIAL RESPIRATION**

Artificial respiration is the most effective means which can be applied in all cases where there is asphyxia, difficulty of respiration or suppression of the latter. Where it is a case of asphyxia by suffocating (drowning, burying, etc.), by electrocution or by poisoning by gas, or of various forms of shock (traumatic, toxic shock, etc.), artificial respiration provides a means of succouring the victim, constituting in such cases the essential principle of treatment. It may be applied in accordance with different methods, the most important of which are as follows: (1) the Sylvester method; (2) the Shaef-fer method; (3) the Howard method.

In the Sylvester method (figs. 106-107) the patient is laid on his back and inspiration and expiration are effected, one by dilatation and the other by compression of the thorax. Movements of the thorax are effected by extension of the arms above the head and a return movement, both executed by the operator.

In the Shaef-fer method (fig. 108) the victim is laid on his stomach and the arms stretched alongside his head. Expiration is produced by the rhythmic compression of the hips and the ribs, performed by the operator, aspiration resulting automatically from the elastic rebound of the thorax to its natural position.

In the Howard method (fig. 109) the victim is laid on his back with his arms folded behind his head. As in the second method, expiration only is performed by the operator, who sits astride the victim and rhythmically compresses the thorax.

The Sylvester method seems to be the most effective, but it is unfortunately very tiring to apply and implies that...
the victim is not suffering from any lesion of the arms or shoulders. Where this is the case, recourse must be had to one of the two other methods.

Artificial respiration must be applied for a long time before being crowned with success. The fatigue which it occasions to the operator necessitates relay work. This demands the presence of several persons trained to apply effectively methods of artificial respiration, which is not always possible.

In 1928 a medical commission appointed by the Italian National Association for the Prevention of Accidents submitted to critical examination the various processes of artificial respiration, and the conclusion reached designated the Sylvester method as the best known and that most likely to induce a high degree of passive inspiration. This method demands little strength, may be practised by one or two persons at the same time, but its application by persons with little skill may cause contusions and lesions of the joints of the scapula and humerus. The Committee esteemed that the manual method suffices to obtain in the majority of cases resuscitation of the victim, but at the same time it recognises the utility of adopting mechanical methods of artificial respiration. Apparatus should be constructed with a view to reproducing as far as possible the Sylvester or Schaeffer method, specially adapted to develop deep, effective and rapid inspiration.

There are on the market at the present time various apparatus which effect respiration mechanically in such a way that the rescue worker is no longer called on to execute more than a simple movement, which permits him to pursue his activity without much fatigue. Thus the "Inhabad" (fig. 110) applies the Sylvester method and the "Panis" (fig. 111) applies the Schaeffer method.

In the case of asphyxiation due to poisoning, notably by carbon monoxide, inhalation of oxygen is a necessary accompaniment of artificial respiration. In other cases this inhalation seems to be a priori useless, though, according to studies and experiments effected in the United States, inhalation of a mixture of 95 per cent. of oxygen and 5 per cent. of carbon dioxide greatly favours recovery of respiration in the case of suffocation in general; particularly in cases of poisoning by carbon monoxide the effects of this gas are more rapidly neutralised than when pure oxygen is administered. Special inhalers based on this principle have been constructed in the United States (inhaler H.H.) and in Germany (Draeger's "Pulmotor" inhaler).

INSTRUCTIONS FOR WORKERS

In certain large establishments where the first-aid station is not within the immediate reach of the workers, the latter receive instructions indicating the steps to be followed in case of accident. Thus, in certain English factories, workers are furnished with the following instructions:

1. Report immediately to the foreman or director every accident, however slight, that occurs.

2. Instructions as to the steps to be followed in case of accident, indicating: the place where the stretcher is to be found, etc.; the place where the ambulance attendant is to be found;
the place where first-aid boxes are kept;
the names of persons in possession of the keys of these boxes;
the name of the special ambulance and the ambulance for treatment;
the name of the stretcher bearers of the section.

3. Note giving a summary of the provisions of the law in regard to industrial accidents and particularly of the provisions relative to notification of accidents, the right to compensation and particulars indicating where the accident register is kept.

Summarised briefly, the steps to be followed in case of accidents sufficiently severe to prevent the patient from moving without assistance are as follows:

- Place the victim in shelter, cover the wound and reduce the discharge of blood by means of dressings, place the affected limb at rest, warm the patient and give him something to drink. Make the most prompt arrangements possible for transporting him to a well-equipped institution by using motor ambulances permitting of the transport of the patient accompanied by a doctor.

FIRST-AID WORKERS

From the above considerations it ensues that very great importance is to be attached to the training of skilled first-aid workers, that is to say, persons sufficiently intelligent and sufficiently trained to understand and to know above all what must not be done. As to what should be done, their professional obligation will be very simple, but should almost always be accompanied by a well-adapted instruction and training in the science of rescue work and the exercises relative thereto.

LEGISLATION

In the majority of countries the laws relative to industrial accident insurance compel the employer to provide first aid for victims of accidents. In other countries provisions relative to first aid are included in orders or regulations relating to the hygiene and safety of workers. Legislation demands of employers that in factories giving employment to a minimum of persons a sick room shall be placed at the disposal of the workers (see article "Factory Surgeons"), or first-aid boxes, the contents of which are sometimes regulated by law or by special orders.

The employer is obliged also to post up the name, address and telephone number of the factory surgeon, and the address and telephone number of the hospital or first-aid station nearest to the factory.

In certain countries legislation regulates the organisation of first aid by laws dealing with special industries, but legal provisions dealing exclusively with organisation of first aid in factories only exist in a small number of countries: Belgium, Great Britain, Union of South Africa, etc.

There may be recalled, by way of illustration, the English brochure and poster dealing with first aid in industrial undertakings (Welfare Pamphlet No. 4, 1929); the German brochure by Gerbis (Organisation des Rettungswesens in Fabriken und Betrieben, 1927); the measures issued in Belgium (17 January 1921) relative to methods of medical first aid; the Italian legislation (General Regulation on Industrial Hygiene of 1927, sections 4-5), as well as the instructions contained in the guide for the application of this Regulation (1929 Edition, pp. 8-12), etc.

Factory medical inspectors have not overlooked the problem of first aid, and in their annual reports they present data concerning the application of measures issued in favour of first aid for victims of accidents. Naturally, this question also interests other occupational categories (naval seamen, mines, etc.), in regard to which there exist interesting reports which it is hardly necessary to analyse here (see, for example, data relative to the organisation of first aid in the English collieries, report by A. J. Cronin, 1927).

The majority of industrial associations for accident prevention have prepared posters with a view to propaganda amongst those affected, relative to the necessity for effective intervention in the case of wounds, accidents, etc. The insurance societies in several countries have not only organised first-class services for providing first aid for victims of accidents, but have also published a series of tracts and propaganda pamphlets for the workers, and even works on the subject intended for medical circles.

Instruction as to the best means of treating patients, in applying first aid, etc., is to-day effected by having recourse to the cinema, and several films have been devoted not only to different methods of medical treatment but also to artificial respiration.

BIBLIOGRAPHY


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The plates have been kindly lent by Mr. Delaunie (Brussels).

Drs. D. Gilbert and M. Stassen (Brussels).

Fishermen

Sea Fishing


The effort demanded by fishing, and the dangers to which workers engaged in it are exposed are strictly related to the particular character of the kind of fishing in question.

There is a great difference between coastal fishing practised with the aid of small boats, trawling, and fishing from a sailing vessel or steamboat; besides which, fishing in the North Sea — differs from fishing off the coasts of Newfoundland, Iceland, or in the Mediterranean. On the other hand, the kind of fish caught, as well as the installation of the boat, the rations provided, etc., all exert an influence on the fishermen's health, so that it is necessary first of all to summarise briefly data relative to these particular factors.

In coastal or small-scale fishing, it is possible for the boats to return after an excursion which, most frequently, does not exceed twenty-four hours. The small boats — generally sailing boats — possess besides, in most cases, an apparatus for mechanical propulsion. On boats of small dimensions, fishermen are exposed to inclement weather, and on those of a certain size such shelter as is provided is of extremely small dimension.

Large-scale fishing is engaged in by steamboats varying in tonnage from 70 to 900 tons, according to the sea in which they are employed.

Fishing in the tropical zones, as well as that effected in the neighbourhood of Iceland, involves considerable risk for the health of the fishermen. In general, work on board sailing boats is more trying than that on board steamboats, e.g. handling the sails and drawing in the nets by means of hand-winch. Steamboats are, on the other hand, provided with mechanical plant, are more spacious and better arranged. It is possible for them, also, to return to port in almost any weather.

Fishing by means of lines obliges the sailors to immerse and to raise often lines 8 to 10 kilometres in length, and provided with hooks and bait. Trawling is less trying, though hauling in the trawling nets is a very difficult operation on board sailing vessels. It is no longer difficult when effected mechanically.

In cod-fishing off Newfoundland or Iceland, the boats depart in March or April and often remain absent for eight months. Cod is subjected to the following preparatory operations: it is gutted, beheaded, boned and scraped, and then thrown into buckets, where it is washed with sea-water and then placed in heaps in brine by the salter, and covered with salt. The character of the work, the use of salt, the risk of wounds from the hooks, the cold, the damp, the long hours involved in preparing the cod, and the life on board, all contribute in rendering the occupation of cod-fishing difficult, fairly unhealthy, and dangerous.

Life on Board

The crew's quarters are forward. Those of the captain, officers, mechanics and the cook are usually aft. The smaller the boat the more restricted are the dimensions of these quarters. For coastal fishing boats having a crew of two to three men, the sleeping quarters are often not over a metre in height. Nevertheless, the crew is obliged to sleep there, since the boat often leaves again in the evening, some hours after unloading the fish.

The cubic air space in the crew's quarters varies with the dimensions of the boat. It is, in general, 4 to 3 cubic m. where there are three persons and over. The bunks have a width which varies from 40 to 100 cm., a length of 1.20 to 2 m., and a height of 90 cm. The surface of the berth is 4 by 2.4 m., and the bunks are placed one above the other in twos.

In wooden boats, the cubic space varies from 2,650 to 2,980 cu.m. per head for small boats, and 2,600 to 3,850 for the larger boats. Similarly, the free surface of the deck varies from 63 to 86 sq. dm. for these boats. There are also "schooners", in which the crew's quarters measure 4 by 4 by 2 m. and shelter a crew of twenty to twenty-five persons.

On steel and iron ships, the crew's quarters have a cubic air space per
head varying between 2.330 and 3.440 m., including the bunks, a free surface of between 61 and 99 sq. dm. per head, though there are, however, quarters where the space is reduced to 60 sq. dm. per head.

On steamboats the quarters have a cubic air space varying from 2.440 to 4.730 m. It is also necessary to take into consideration the fact that a large part of the space is taken up by various objects, boxes, etc., which the fishermen place in their quarters, and in addition to that they often do their cooking there.

By way of comparison with the above figures, which were obtained by measures effected on board ship, it is interesting to recall that the German legislation demands a cubic air space of 3 to 3.50 m. per head, which figures are increased to 4 m. by the Dutch and French laws. Where cooking is effected in the crew's quarters, the cubic space demanded should be at least 5 m. per head. The great obstacle in this connection is determined by the fact that the cost of construction, maintenance, and working of the ship increases with its dimensions, and that the maximum space possible is desired for the cargo. Hence the small amount of space reserved for machinery and for the crew. Steamboats have a special storeroom, which constitutes considerable progress (fig. 112).

The lack of space would present less inconvenience if better ventilation were possible. This is not, however, the case, since navigation of the ship prevents the construction of larger port-holes or window panes. On the other hand, such openings as exist must be entirely closed in stormy weather, and the vitiated air may only be evacuated by means of pipes, the dimension of which varies between 15 and 20 cm.

Light is obliged to penetrate into the quarters by side port-holes, prismatic glasses encased in the deck, and panes of glass. In general, it is insufficient, and artificial light requires to be used day and night, being provided by oil or petrol lamps, by candles or by cod liver oil. Modern ships of large dimensions possess electric light installations.

The following figures give an idea of the CO₂ content and the humidity rate of air in the crew's quarters, engine-rooms, etc.
Ventilation being, in these conditions, very bad, it is advisable to construct an open square space in front of the crew's quarters. The men will then be better protected, especially when the ship is sailing against the wind, and in stormy weather. On small fishing smacks, where access to the crew's quarters is gained by means of a small, almost vertical ladder, ventilation is practically impossible in bad weather. The atmosphere is therefore often repugnant and, as the men like the heat, they remain in a closed space in an atmosphere vitiated by tobacco smoke, the odour of oil, and body exhalations of the men, who are often uncleanly.

The description given by Cazeau applies to quarters on boats engaged in large-scale fishery, and the situation is only improved when the duration of the voyage is relatively short. As a general rule, however, it may be said that there is much to be desired from an hygienic point of view, though differences of race, nationality and mentality count for something in this connection.

As regards ventilation, the situation might be improved by providing the quarters with a sliding door, and by an adjustable fanlight of at least 45 to 90 cm. As ventilator there might be used air holes the form of a mushroom head or long, narrow neck ("Swanneck"), which give fairly satisfactory results. The latter model occupies less space, but presents the disadvantage of having to be closed during bad weather (fig. 113).

The heating is effected by iron stoves burning coal or by furnaces. The products of combustion are eliminated by a pipe which, in a contrary wind or in case of an escape, permit smoke and toxic gases to be liberated in the quarters.

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</table>

FIG. 113. — Mushroom-shaped ventilators.

There is no special place set apart for washing purposes for the crew. The men are given a pail of fresh water for washing. Further, the men have an aversion to undressing in cold, bad weather, and the long hours of night work, together with fatigue, often prevent them bestowing any time on their toilet. Further, their heavy, thick clothing, which often weighs from 6 to 6½ kg. without including their boots and sou'westers, is difficult to clean. The Americans have replaced these heavy boots by rubber boots. The risk of drowning in case of falling into the sea is, in this way, diminished.
The crew's quarters are, in general, cleaned out by the cabin boy. The presence of vermin in the straw mattresses demand, on return from a voyage, disinfection by means of a Clayton apparatus, but more frequently the mattresses are thrown overboard. Mattresses of kapok are not used on account of their high price, which prohibits destruction at the end of the voyage. Sanitary accommodation is usually lacking on most boats, and the crew use simple buckets. Wherever sanitary accommodation is provided, it is often in an uncleanly state and, through lack of proper covering or closing, the sea water is able to enter.

A provision of drinking water is obtained in port and placed in tanks or, in the case of small boats, in wooden barrels. Steamships have tanks containing 5,000 to 15,000 litres, whilst wooden ships, especially those engaged in the herring fishery, are often only provided with tanks which are unduly small in proportion to the number of men on board. It is necessary to calculate 14 litres of water per head per day and, apart from that, 7 litres for cooking and washing, and 6 litres for washing of clothes, making in all a total of 144 litres per day.

As the water barrels are often made of oak, the water acquires a brown colour, and becomes unfit for drinking. An analysis of water on board on the last day of a voyage, effected by J. C. Mom, gave the following results in milligrams per litre:

<table>
<thead>
<tr>
<th></th>
<th>Chlorine</th>
<th>$\text{KMnO}_4$</th>
<th>Iron</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam trawler, tank</td>
<td>60</td>
<td>24.4</td>
<td>1.5</td>
</tr>
<tr>
<td>Steam trawler, reser-</td>
<td>44</td>
<td>6.9</td>
<td>1.0</td>
</tr>
<tr>
<td>voir in cemented iron</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cutter, new reservoir</td>
<td>36</td>
<td>8</td>
<td>1.5</td>
</tr>
<tr>
<td>in cemented iron</td>
<td>60</td>
<td>8</td>
<td>1.0</td>
</tr>
<tr>
<td>Lugger, iron reservoir</td>
<td>60</td>
<td>8</td>
<td>1.5</td>
</tr>
<tr>
<td>Lugger, oak reservoir</td>
<td>49</td>
<td>12</td>
<td>1.0</td>
</tr>
<tr>
<td>Bomm, wooden reservoir</td>
<td>41</td>
<td>106</td>
<td>1.0</td>
</tr>
<tr>
<td>Line-fishing boat, oak reservoir</td>
<td>48</td>
<td>47</td>
<td>1.0</td>
</tr>
<tr>
<td>Filtered town water</td>
<td>32 to 34</td>
<td>6.8 to 8.5</td>
<td>1.0</td>
</tr>
</tbody>
</table>

In the majority of countries there exist legislative provisions in regard to the rations for sea fishermen. These are, in general, sufficient, but are monotonous and badly prepared. Fish, bacon, meat, peas, beans, bread, biscuits, pancakes, cheese and margarine form the principal kind of foods.

The various lists of provisions differ according to the length of the voyage, the nationality of the fishermen, and their habits. In general, fishermen consume much alcohol, and the trying living conditions favour this consumption. Diseases met with formerly, which were due to lack of certain food elements (absence of vitamins), are rarer at the present time, which is due to improved technique in the preparation of tinned foodstuffs.

The relatively small wages, subject to fluctuations in the price of fish, influence the living conditions of fishermen when in port. Their wives and children are obliged to work in order to provide an adequate living wage for the family — the women work in mending nets, preparing tinned fish, in the smoking and drying factories, and in the canning of fish, in fishing for shellfish and shrimps, or in gathering seaweed on the coast, or else they take on daily work. Fishermen thus exercise a hard trade, which is further saddened by the repeated departure of the men and young boys, and the dangers to which they are incessantly subjected. The kind of life which they are obliged to lead probably influences their character, usually that of simple and devout men with few needs, with a rough and taciturn manner, and an appearance which is far from amiable.

**Statistics**

French statistics indicate that out of 14,218 men engaged in large-scale fishery, 352 died during voyages which lasted six months (25 per 1,000). In 1902, 9,980
French sailors were engaged in fishing off Newfoundland, being distributed over 426 ships: 305 of these men died, 17 in a shipwreck, 87 as a result of accidents, and 201 as a result of wounds and sickness (26.8 per 1,000). The mortality rate for miners at the same period was only 5 per 1,000. The figures showing the incidence of typhoid fever were also very high. In 1902, out of 107 fishermen suffering from typhoid fever in the hospitals of Newfoundland, there were 27 fatal cases. In 1903, out of 162 cases of sickness there were 20 deaths.

The figures relative to the mortality rate for fishermen in Great Britain were 964 for the period 1890-1892; 892 for that from 1900-1902; 858 for that from 1910-1912, and 630 for that from 1921-1923.

Dutch statistics give the following figures:

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Total number of persons occupied</th>
<th>Number of deaths</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fishermen</td>
<td>24,882</td>
<td>680</td>
<td>2.77</td>
</tr>
<tr>
<td>Agricultural workers</td>
<td>356,500</td>
<td>18,344</td>
<td>5.14</td>
</tr>
<tr>
<td>Miners</td>
<td>847,297</td>
<td>21,171</td>
<td>2.52</td>
</tr>
<tr>
<td>Transport workers</td>
<td>1,160,684</td>
<td>33,660</td>
<td>2.95</td>
</tr>
<tr>
<td>Intellectual workers</td>
<td>276,164</td>
<td>6,910</td>
<td>2.50</td>
</tr>
</tbody>
</table>

Dutch statistics give the following figures:

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Mortality at the age of</th>
<th>Mortality caused by:</th>
<th>Average mortality calculated for all diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>35-44 years</td>
<td>45-54 years</td>
<td>Pulmonary tuberculosis</td>
</tr>
<tr>
<td>Fishermen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fishermen engaged in river fishing</td>
<td>4.06</td>
<td>6.17</td>
<td>1.11</td>
</tr>
<tr>
<td>Seamen engaged in marine navigation</td>
<td>11.24</td>
<td>16.33</td>
<td>2.34</td>
</tr>
<tr>
<td>Boatmen engaged in inland navigation</td>
<td>5.79</td>
<td>14.91</td>
<td>1.31</td>
</tr>
</tbody>
</table>

CAUSES OF DEATH IN THE NETHERLANDS FROM 1898 TO 1903 (PER 1,000)

Pathology

The diseases and accidents affecting fishermen are, as has been stated, strictly in relation with the conditions under which their work is effected. Trying work during long hours explains the incidence of arteriosclerosis, the development of which is favoured by alcoholism and the consumption of tobacco, especially tobacco chewing and snuff-taking. The physical effort demanded often exposes fishermen to the risk of hernia. The monotonous life led by them has been held to be one of the causes of
the debauched existence which they lead when in port. In consequence thereof venereal disease is frequent among seamen. Lack of cleanliness, moreover, favours the development of parasites, itch, ringworm, which has been reported as affecting fishermen who work up to the waist in water (Rille).

The various influences of the weather (sun, wind, rain, sudden change of temperature, etc.) often lead to an unusually high morbidity rate for acute and chronic respiratory affections. Obstruction of the naso-pharyngeal passage, complicated with catarrh of the middle ear, is also fairly frequent.

Data relative to the incidence of tuberculosis amongst fishermen varies very considerably and is not always reliable. According to French authorities, pulmonary tuberculosis is said to be very frequent, whilst the figures for Norway, Great Britain and the Netherlands point to more favourable conditions. It is probable that the bad hygienic conditions existing in the crews' quarters are to some extent compensated by the advantage of life in the open, as led by seamen; perhaps organic resistance is increased by the substantial rations which they receive. Nevertheless, a slight attack of lung disease may be sufficient to cause the conditions to which they are exposed to exert an accelerating action on the evolution of lung disease.

Acute and chronic rheumatism is one of the diseases most commonly met with, and is attributable to exposure to inclement weather. Amongst older fishermen several cases of deforming arthritis have been reported.

The occupational diseases typical of fishermen are due to the various operations in which they are engaged. Firstly, there is the action of brine and salt water on the skin which, especially in the case of wounds, leads to dermatitis. The preparation of herrings has been studied in regard to this problem, and the different operations, often accomplished by women (gutting, salting, packing, etc.), favour the development of skin diseases. The latter comprise a form of pustular dermatitis, usually localised on the under side of the fore-arm and occurring more frequently amongst the packers than amongst the salters; deep, painful or painless ulcers ("hous") are situated at the sides of the nails, their size varying between a pin point and a threepenny piece. The latter are found more frequently amongst the gutters and resemble chrome ulceration. Where there is no complication (cellulitis) these lesions heal relatively easily. However, they present a very obstinate character when it is not possible to suspend work. The secondary infections complicating these forms of dermatitis are fairly frequent, especially amongst the packers, in whom they assume an erisypeloid aspect.

The handling of cables and wet ropes and frost-bite of the skin often give rise to deep fissures of the skin, espe-
cially amongst fishermen working in northern climes.

Toxic infectious conditions are often caused by pricking by fish bones and cuts from shells of sea shellfish. Pricks from fish bones may heal easily, but sometimes they may be serious and accompanied by toxic phenomena due to the fact that certain fish are venomous.

Ocular troubles have been observed amongst fishermen or those handling fish (fishmongers). Thus, for example, there may be mentioned the special form of conjunctivitis caused by handling eels and due to the action of their blood, which causes redness of the eyelids, conjunctival hyperaemia (especially of the ocular conjunctiva), watering of the eyes and a burning sensation.

The toxic action of serum prepared from eels is said to be due to the presence of an ichtyotoxine brought to light by Mosso, and studied by Gauthier and Calmette. In one case, besides conjunctivitis, there was also slight superficial peripheral keratitis (Oblath). Research has demonstrated the fact that the bile of the eel is likewise capable of giving rise to a slight form of conjunctivitis (Oblath). Keratitis have been observed as affecting oyster sellers (Dowell, Hiram Woods); the condition in question is a traumatic lesion of the cornea due to small fragments of the oyster shell which may be projected into the eye during opening of the oysters. These fragments are quickly eliminated after having produced a circumscribed and

not very deep necrotic area on the tissue. Where infiltration of the cornea is extensive it may assume a more serious character and may even go as far as causing an opening of the anterior chamber and even to panophthalmitis. Bacteriological tests (Randolph) have always been negative, and it has, therefore, been concluded that the violence of the lesion of the cornea is to be ascribed to chemical substances contained in the shell, and perhaps especially to calcium carbonate.

There has, however, been observed amongst fishermen a form of cataract due to larvae of trematoda (Greef) connected with the excrement of seagulls found on the skin of fish. The infection takes place by ingestion of in-

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**VENOMOUS FISH**

It is known that the number of species of venomous fish is to-day
estimated at about 150 and that their presence is more frequent in hot climates than in temperate or cold climates. Scientifically, distinction should be made between “venomous fish” and “poisonous fish”. The former are those which harbour venomous substances in the glands in the skin or in the serum of the blood, the harmful effect of which is exerted on the blood (hemolysins leucotoxines) as a result of bites or pricks, on the heart, on the nervous system (neurotoxins) and on the tissues. The latter are those which harbour physiologically (by means of normal, permanent, or temporary activity) substances which provoke, on ingestion, symptoms of disease. It is the first category, which are of interest here, comprising fish which distil their venom by way of the teeth, fins, etc. Amongst these is the Trygon pastinaca, which are of interest here, comprising the Trygon pastinaca causes, as a result of bites, very painful phenomena of poisoning which are long in healing. This species is well known and much feared by fishermen. The species Trachinus vipera, draco, radiatus, argusus, cause very painful symptoms which, however, heal rapidly. There have been known cases of this type of poisoning which give rise to fever and delirium, vomiting and syncope.

In hot climates the most venomous species of fish are the Synanceia verrucosa L. (known on the coral reefs of the Indian Ocean), the venom of which causes very serious and often fatal accidents; the pelor which inhabits the seas around Japan and China; the pterois of the Indian Ocean, etc. The proper treatment of such bites consists in cauterising the wound to cause bleeding, followed by the application of alcohol or ammonia. In certain cases internal administration of alcohol and cardio-tonic injections are necessary.

The species Murcena helena L. represents the only species of fish which possesses poison teeth, the venom-secreting apparatus being situated in the mucous membrane of the buccal palate. The toxicity of the venom of this fish is extremely high, since 24 mg. of the aqueous extract from the palate of the murocena injected into the veins of a guinea-pig causes death in a few minutes. This fact explains the fear in which fishermen hold the bites of this fish, bites which are very painful and extremely slow in healing.

Contact with sea-nettles causes a burning pain, followed a day later by violent irritation. The dry toxin of the sea nettle becomes mixed with the dust in the nets, with the result that fishermen handling these are exposed to sneezing and watering of the eyes.

In conclusion mention should be made of fish which constitute a risk for fishermen by means of electric discharges, notably those of the species Torpedo marmorata.

**Accidents and their Sequelae**

The sequelae of disease symptoms and accidents are not infrequently more serious than what the early stages of these would lead one to expect. This results from the fact that medical care at the outset is, in most cases, lacking, and that often individuals who are seriously ill or are the victims of serious accidents require to be transported for great distances before receiving medical attention. Regulations concerned with the health supervision and the provision of medicaments have for long proved illusory in the different countries which send schooners to Newfoundland, Iceland and Greenland. At the present time control of the work in question is effected from State buildings in the neighbourhood of the fishing stations, in addition to which shipowners at times charter and equip hospital ships (Van Leet).

**Legislation**

Legal provisions are generally concerned with ships belonging to the mercantile marine and steamers, rarely with fishing vessels. They relate, amongst other things, to the navigability, to the cubic space, first-aid boxes, etc. (see article "Seamen").

Thus, in the American, Italian and French laws there are found provisions relative to navigability; in the American, Danish, English and French laws, provisions relative to the cubic inch space; while the German regulations only contain certain provisions of a general order.

There are, in various countries, provisions relating to the hygienic conditions on board. Thus the Dutch, English, German, etc., laws provide regulations relating to medicaments and dressings which must be provided in sufficient quantities on every boat. Apart from that, in almost all countries measures have been taken relative to rations on board, to drinking water, etc.

Special legislative measures relative to pearl fishing and sponge fishing have been set up in several countries, especially when it is effected by diving. Thus, for example, in Egypt (8 September 1926, No. 12 relative to sponge fishing), in Western Australia (21 April 1926), Venezuela

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1 For affections noted amongst divers (sponge and pearl fishers), see article "Divers".
In 1924 it was estimated that throughout the world there were 2,917,000 spindles, distributed thus:

<table>
<thead>
<tr>
<th>Country</th>
<th>Spindles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Britain and Ireland</td>
<td>160,000</td>
</tr>
<tr>
<td>France</td>
<td>450,000</td>
</tr>
<tr>
<td>Russia and Baltic provinces</td>
<td>358,000</td>
</tr>
<tr>
<td>Belgium</td>
<td>331,000</td>
</tr>
<tr>
<td>Germany</td>
<td>230,000</td>
</tr>
<tr>
<td>Czechoslovakia</td>
<td>250,000</td>
</tr>
<tr>
<td>Italy</td>
<td>55,000</td>
</tr>
<tr>
<td>Austria-Hungary</td>
<td>12,000</td>
</tr>
<tr>
<td>Poland</td>
<td>10,000</td>
</tr>
<tr>
<td>Netherlands</td>
<td>8,000</td>
</tr>
</tbody>
</table>

Based on Gilbert's study of the industry and on the number of spindles, an approximate figure can be given of the number of persons of both sexes employed in the linen factories of the world. The Belgian enquiry made it out to be 12,275 persons for the number of spindles, which was obviously the tenth of the actual world figure. The linen industry, therefore, can be said to employ at least 125,000 persons. The usefulness of a study of the hygiene of the industry is apparent, and becomes still more so if it is extended to cover workers engaged in preparing linen cloth and spinning and weaving of tow (gathering, retting, stripping). The last-named categories of workers, however, do not belong to a specialised occupation, which creates difficulty in ascertaining their number.

It must be noted, moreover, that difficulty arises in properly distinguishing between spindles for linen and spindles for hemp, as this latter, after undergoing a supplementary preparation of the fibres, is worked on the same machines, and, with scarcely any difference, by the same processes as is linen.

What has been said above can be summarised by quoting from the official report of the fifth Congress of the Textile Industries held in Vienna in 1914, which states that the area in the world devoted to the cultivation of flax amounted in 1913 to 16,545,816 acres. Assuming an average yield, under rather than over estimating, of 5 quintals of flax per hectare (3.471 acres), this would give a total yield of 82,829,680 quintals. The largest producers of flax were at that time the Argentine Republic, India, and European Russia.

The particular qualities of the different kinds of flax exercise a marked influence on the methods of conducting the processes to be followed, and naturally also on the hygienic conditions of the atmosphere in which they are carried on.

Generally speaking, the highest qualities of flax are French and Belgian. That of Courtrai was formerly considered as the finest in the world. Russian flax is of average quality. These differences depend mainly on the methods adopted for retting.

Although less sensitive to the action of a hot, humid atmosphere than cotton, linen does not escape being notably influenced by it. Thus linen containing 7.25 per cent. of moisture in an atmosphere of which the relative humidity is 44 per cent., according to Muller, holds 11.04 per cent. in air with 75 relative humidity. The
Lincoln fibre is composed of very fine filaments held together by a kind of gum resin soluble in water but which, by undergoing solution, imparts certain physical properties such as strength and particularly elasticity, in increased measure. Classical experiments by Professor Otto Wilkomm show that the breaking point of the linen fibre increases at first slowly until it reaches a relative humidity of 70 per cent. Above that the increase is more rapid. If the breaking weight be 6.2 kg. at relative humidity of 40, it is 6.7 at 70 and 7 at 83; it follows that industrially beneficial results follow by treating the linen fibre in a moist atmosphere. This condition is completely realised in what is called "artificial wetting", but adoption of the method will only be necessary to mention, as they give rise to abundant and harmful dust. The residual boony fibre, very combustible, is used in the artificial retting establishments for heating the water used, and constitutes one of the economies of the process. The real raw material for flax spinning, the unspun fibres, are thus obtained.

They are used as they are, or are cut into two or three portions if the flax is of a very long quality.

The processes then follow one another in the following order:

(a) Hand or machine hackling.
(b) Preparatory processes of spreading and drawing on fly or roving frames.
(c) Dry or wet spinning.
(d) Winding.
(e) Drying.
(f) Packing and baling.

Hackling and the preparatory processes make tow, which is treated first by carding, other operations being the same as for the unspun fibres.

**Hackling**

Hackling is done with a view to separating the fibres one from the other, which has not been effected by the scutching operations, extracting all the foreign matter still adherent to them and removing short fibres and irregular fibres like tow. Hackling is now done by machinery, but hand hackling is also done in two subsidiary processes — roughing and finishing.

The workman seize a bundle of flax, divides it into handfuls or "sticks" and draws it through the hackle pins first one end and then the other. The hackle consists of strong metal pins fixed on a block of wood, which is in turn attached to a support (the hackle). The biggest quantity of tow and nodes is got rid of in this process. As the work progresses stricks of the hacked material are loaded on to special trolleys and taken to the machine hackles.

Finishing is only done on high quality material intended for high counts. The finisher divides the hacked bundles as they leave the machine and passes them successively through two hackles — one fine and the other excessively fine. Behind is the tow box. The fibres are then almost completely separated one from the other and thus brought parallel: they are ready for later opera-
tions necessary to prepare the material for spinning.

The hackling machines usually employed in France and Belgium are modifications of the early type of Philip Girard. The flax stricks coming from the roughing process are placed in metal clamps which hold them by the turn of a screw. More than half the length of the material hangs below the lower part of the clamp. Once filled with flax the metal clamps are held in position by a metal slide extending the whole length of the machine and known as the carriage or guide rail for the clamps.

The metal slide moves up and down in a vertical direction, rising and falling with the metal clamps and their contents, which at the same time are moved over pins carried on lattices with displacement perpendicular to their length. These lattices are united by leather straps which revolve round cylinders provided for the purpose. The portion of flax is thus hackled simultaneously on both sides by the rows of pins placed one another, and becoming finer and finer as they approach the extremity of the machine. Every time that the carrier arrives at the end of its course a special mechanism, the clamp changer, allows of one lot being taken out and another introduced at the other end. The clamp driven out is caught by another mechanical contrivance, the change over loop, which unlooses the binding screw so that the flax strick can be reversed, the root end now being fixed in the clamp and placed in another machine. Fifteen years ago all this mechanical work was done by children of 12 to 17 years of age. By the time it reaches the end of the second machine the flax has been completely hackled. The tow is removed from the hackle pins by means of a circular brush, which in turn is stripped by a doffer. From the latter the tow is removed by a revolving device known as "doffing-knife", which causes it to fall eventually into the tow box.

The youthful workers employed in feeding the machines are called machine-boys. Juvenile labour is preferred for this work for several reasons, the principal being that rapidity of movement is required, of which children only are capable, and that the wages are not high for the work rendered.

Placed at one extremity of the hackling room, these children seize a strick of flax coming from the roughing process and range it in the clamp, which they have previously unscrewed; then they seize it with both hands, to let it slip into the carriage, lifting it vertically about 80 cm. But the weight of one of these clamps loaded is 5 kg. and the rhythm is fixed at 5 clamps a minute, that is, 300 an hour, so that in one hour the effort equals the raising of 1,500 kg., through a height of 80 cm. In raising the clamps, therefore, alone, an effort of 1,200 kilogrammetres per hour is made. The total effort, therefore, may be reckoned at 1,300 kilogrammetres if the accessory work done in grasping the bundles of flax and screwing and unscrewing the clamps is estimated at 10 per cent. only.

An enormous quantity of dust is created by the hackle pins in contact with the fibres and of the brush against the doffers.

**Spreading and Drawing**

The object of spreading and drawing is to connect the stricks of flax into a continuous riband, and to bring this to such a degree of fineness and homogeneity that when it is uniformly twisted it should yield a thread of constant diameter. Spreading and drawing machines are used for this. The spread-board consists of an endless belt moving on rollers on which the expert workwomen place the flax stricks to be combed one behind the other without any break in continuity and as regularly as possible. Two rollers, with the material caught between, conduct each layer to a series of bristling rows of steel pins known as "gills". They prevent the riband from breaking under the stress of the drawing rolls between which it travels after leaving the gills. Flattened in the process the ribands become a sliver. Several slivers are joined up so that their irregularities compensate one another by passage over the doubling table, and at last they are collected in a cylindrical can.

This operation produces dust lighter and finer than that of hackling. Drawing means taking from the spread-board the sliver which is still far from sufficiently regular, and giving it regularity by repeating the drawing operation two or three times, doubling it and lengthening it over the gills.

The first drawing takes the slivers coming from several cans at the same time; they are doubled over gills, similar to those of the spreading board, and functioning in exactly the same way, but with finer teeth. This fineness is increased at every drawing, and finally a sliver is obtained of sufficient homogeneity and corresponding exactly to the quality of the thread ultimately to be obtained.

The process of drawing is continued on roving frames, but instead of being
collected in a can the sliver coming from it undergoes a slight twisting and is wound on to a bobbin. This twist makes the sliver into a rove, which is more solid and facilitates spinning.

Drawing and roving continue to separate the fibres one from the other and to break the dry skin uniting them. They also create dust, but of a finer and finer kind.

**Spinning**

Dry spinning is done for linen thread on counts of 1 to 25 and for tow from 1 to 20; wet spinning is practised on finer counts.

The spinning frame is nearly always a continuous process, but at Lomme (near Lille) interesting experiments have been made in mule spinning.

The rove comes from the bobbins of the roving frame and is carried by cylindrical rolls, between which it passes to the spinning frame which can be fly spindle or ring. This rove undergoes twisting which transforms it into a thread rolled on a bobbin. In wet spinning the rove coming from the large roving bobbins is made to pass through a trough of water at a temperature of 60° to 80° C. according to the number of counts in question. This water softens the dry gummy matters round the fibrils, in such a way that the twisting, which follows immediately the passage through the warm water, agglutinates the fibres together, making the thread both more homogeneous and more solid.

While the workers are exposed to the inhalation of dust during dry spinning, during wet spinning they suffer from excessive humidity of the atmosphere and high temperature.

The work of spinning properly so called is then complete.

There only remains to do up the thread into hanks for the market, dry them if necessary, and pack them for transport to the weaving shed or yarn factory.

**Preparation of tow.** — The short and irregular fibres after hacking remain in the tow box. These, although a residue, constitute none the less a textile material of some value. Other fibres come from the cleaning of the preparing machines. As they have been separated without any special care into the receptacles, they consist of a confused mass and are very knotted and twisted. To bring the fibres parallel to one another recourse cannot be had to hacking. To do this another machine — the card — is used. First the tow is subjected to a preliminary hand sorting and mixing which gives off such copious dust that watering of the layers of tow is necessary. This watering has also the effect of supplying the needful amount of moisture for suitable carding operations.

The card is essentially a great cylinder or drum with a movement of rotation on its own axis, which is horizontal, and the surface of which is studded with teeth inclined in a tangential direction. Around this drum are other smaller cylinders placed tangentially to the large one. They are also provided with sharp teeth sloping some in the direction of movement and others inversely to it. According to the function they perform these cylinders go by various names, "workers", "strippers", etc.

The tow is arranged in as regular a manner as possible on an endless belt by a female carder. It passes through two feeding rolls and then traverses the different parts of the card, to emerge finally in the form of a riband which can be manipulated just like the long fibres.

Work on the card is very rough. It breaks the fibres, pulverises the interstitial tissue and produces a cloud of dust, thicker even than that given off by the hacking machines.

**Reeling or Winding**

The bobbins coming from the spinning frames are carried to the winding room to be arranged in hanks. The operation is carried out on a machine carrying hexagonal winders easily lifted from their supports, in order to allow the hanks to be lifted from them as they are formed by the flax unwound from the bobbins, mounted on a framework of pegs. A bell rings when the requisite length of hank has been wound.

**Drying**

After wet spinning, excess of moisture, which would set up injurious fermentations and interfere with the final strength of the thread, must be removed. The hanks are hung up on poles in a drying chamber, which is often heated by the waste heat from the furnaces. Frequently flanged radiators are added and often also fans drive hot air into the dryer. The person engaged in drying must keep an eye on its progress and remove the dried hanks.

**Packing**

Drying makes the fibres stiff from the dried gum. They are softened by shaking and successive twisting over a round
wooden post fixed horizontally to the wall. This work is very tiring and is only taken on by strong workers.

There remains then only to tie the hanks up in packages ready for the market.

Drying and packing are undertaken by the same workers, who are more than any other class in the industry exposed to the diseases attributable to variations in temperature.

**Pathology**

In the majority of the processes of linen spinning the great enemy of the workers is dust. In wet spinning moist heat has to be considered more than in any other industry. The humidity, in conjunction with the effects of the work itself, is apt to produce local affections. In drying, chills from draughts have to be feared.

The other accessory workrooms are without special risk deriving from the work done there.

The workers consider that, apart from the offices and stores, the healthiest workroom is the winding room.

The dusts produced in the working of flax are mineral, vegetable and organic. Gilbert and his assistants, after counting them, obtained figures as follows:

<table>
<thead>
<tr>
<th>Workroom</th>
<th>Dust per cubic metre of air</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vegetable</td>
</tr>
<tr>
<td>Hand hackling</td>
<td>94,828</td>
</tr>
<tr>
<td>Machine hackling</td>
<td>74,824</td>
</tr>
<tr>
<td>Preparing</td>
<td>171,866</td>
</tr>
<tr>
<td>Carding</td>
<td>381,451</td>
</tr>
<tr>
<td>Winding</td>
<td></td>
</tr>
<tr>
<td>Spinning</td>
<td></td>
</tr>
<tr>
<td>In the open air</td>
<td></td>
</tr>
</tbody>
</table>

The abundance of mineral dust is due to the fact that the stem of the plant is rich in silica. But siliceous dusts are recognised as being amongst the most injurious; in the case in point, there must also be considered their acute-angled fracture, which causes damage to the mucous membranes and facilitates the entrance of pathogenic organisms.

According to Gilbert, the particular injuriousness in flax dust is largely due to its richness in silica. The silica is more abundant in the stem than in the fibre; the most injurious processes are those having principally for their object to rid the fibres of the woody debris given off in hackling. The presence of a gummy matter contained in the fibres, and perhaps also the products of vegetable putrefaction and of moulds, increases this harmfulness.

The operation of hackling is very dusty, and the operations relative to mechanical hackling further constitute an important cause of fatigue. Carding is even more dusty than hackling; in this department a perfect cloud is caused, rendering the work very unhealthy. Preparation is less injurious than the others. A small enquiry made in 1910-1911 by Bargeron into the health of hand hacklers revealed that most of them coughed and that all were addicted to alcohol, because they alleged that drink prevented their feeling the irritation in the throat. The situation is always the same. Alcohol assists in starting and developing consumption.

Verhaegue, of Lille, also had occasion to examine 41 hand hacklers, of whom 28 were the victims of chronic affections of the respiratory tract. He estimated that more than half of those of the workers who suffered from a cough in the textile industry were victims of pulmonary tuberculosis.

No recent precise data exist as to the frequency of tuberculosis and respiratory diseases among linen workers. There is general agreement everywhere that pulmonary tuberculosis is fairly high among the workers engaged in this industry, but rather old statistics only are available; according to these of 1,000 spinners 221.6 of the workers were ill, and among 1,000 weavers 202.7; it is not, however, stated whether the spinners and weavers were employed in linen, cotton, or wool manufacture.

Linen workers are also exposed to mill fever, an affection which generally lasts three or four days, and, as in the case of other textile workers, is probably due to the phenomenon of anaphylaxis. The asthmatic attacks these workers suffer from are certainly connected with the inhalation of dust. They are accompanied by a spasm of the bronchial muscles and swelling of the mucous membrane, and pretty often compel the worker to give up work.
after a short duration of employment. Koelsch attributes the fever to a mould analogous to that causing fever and asthma among cotton weavers. It should be recalled that this malady arose when the treatment of the cotton with a solution of chloride of zinc (Lehmann) had been abandoned. Cases of pneumonia and bronchitis are frequently described among the spinners. It is said to be due to the bad habit of using the warm water from the troughs to wash in; others consider it to be a secondary localised industrial eczema; and others again merely the consequence of humidity and a high temperature.

The upright posture causes in the end fatigue as well as circulatory troubles, varicose veins, and internal troubles especially among women, etc.

An enquiry made by Akim (1923) among the linen factories of Kostroma (Russia) employing 6,000 workers, of whom about 60 per cent. were women, was directed especially to the influence of the occupation on pregnancy. The data were collected during a period of three years (1908-1910), but naturally too many external factors were liable to interfere with those concerning the occupation, so that the figures have only a slight value, although the spinners have a figure for miscarriages and premature births rather higher than that of the wives of spinners who did not work in the factory:

<table>
<thead>
<tr>
<th></th>
<th>Wives of spinners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cases of pregnancy</td>
<td>1,126</td>
</tr>
<tr>
<td>Normal confinements</td>
<td>957</td>
</tr>
<tr>
<td>Abnormal confinements</td>
<td>957</td>
</tr>
<tr>
<td>Per 1,000</td>
<td>830</td>
</tr>
<tr>
<td>Premature confinements</td>
<td>74</td>
</tr>
<tr>
<td>Per 1,000</td>
<td>4</td>
</tr>
<tr>
<td>Miscarriages</td>
<td>4</td>
</tr>
<tr>
<td>Per 1,000</td>
<td>48</td>
</tr>
<tr>
<td>Still births</td>
<td>10</td>
</tr>
<tr>
<td>Per 1,000</td>
<td>17</td>
</tr>
<tr>
<td>Illnesses during pregnancy</td>
<td>15</td>
</tr>
<tr>
<td>Per 1,000</td>
<td>15</td>
</tr>
<tr>
<td>Mortality in confinement</td>
<td>5</td>
</tr>
<tr>
<td>Per 1,000</td>
<td>5</td>
</tr>
</tbody>
</table>

Gilbert’s enquiry, although dating back to 1901-1902, has remarkable practical value because it comprises 12,275 persons, of whom 3,485 were men and 8,790 women. The latter numbered 90.04 per cent. among the spinners, 94.29 among the preparers, and 71.88 among the carders.

Gilbert was able to show that the proportion of women workers in good health was low (56.86 per cent.) in the spinning rooms, where the majority of the persons under 20 years are employed, and have a tendency to quit the work after a brief period of employment. The number of persons in good health in the carding rooms is higher than that in the spinning and preparing rooms, but the labour turnover is higher than in the preparing rooms.

Duration of employment in the spinning rooms retards development of female employees.

As regards morbidity this is lowest for the persons engaged in preparation, and contrary to the class of work this period of incapacity due to illness is shortest. Next in order come “other occupations” and drying. Hackling and carding are the worst operations from the health point of view, whilst spinning occupies a better position. The winders, on the contrary, showed more cases of sickness than the carders, and a longer duration of sickness than the spinners.

Without exaggerating the facts, one has to admit that the morbidity rate in this industry is striking.

In 1912 Imbert and Bargeron undertook research into the conditions of living and health of the young persons employed in machine hackling. The results have never been published owing to the war and the death of Mr. Imbert. The observations, however, were made on ten young workers employed in a factory in the centre of Lille, aged from 13 to 15 years. Their weight varied from 29 to 50 kilos; their pulse was rapid, varying from 90 to 105. Four coughed, of whom two were undoubtedly tuberculous. Their food was unsatisfactory and, as is customary in the North of France, consisted largely of coffee and bread and butter. But a significant fact was that these lads, whose hard work has been depicted above, drank gin like their elders early in the morning in order to blunt the taste of the dust.

This confirms the earlier statements of Lefebre: “The children engaged in machine hackling have the roughest work to do in flax spinning”; and the conditions of employment explain what Gilbert found, namely, that of one hundred workers who entered on hackling at 12 years of age only eight reached the age of 40 years, the average duration of employment having been only seven and a half years, i.e. the shortest in any industry.

The invention of the automatic feed to the hackling machines has certainly been one of the greatest advances in industrial hygiene during the last twenty years, simply because it has led to the suppression in this class of work of at least half the young persons.

Accidents are very rare in hand backing. They are not so very frequent either in machine hackling. As characteristic have been considered (Guermonprez) tearing wounds of the skin of the hands and forearms of the persons who,
when trying to clean the machines, are caught between the layers of hackles.

The card machines have always been regarded as the worst in linen factories so far as evolution of dust is concerned. Robust women are always chosen; nevertheless, they do not stand it for long. Arlidge cites Purdon as saying: "A woman commencing carding at 17 or 18 years commences to break down at 30 and the average life of a carder is about 45 years".

Gilbert, who confirms this view, justly says that the dust from the carding machines may partly owe its injurious nature to the presence of fine metallic particles derived from the friction and breakage of the fine steel points of the cards; these particles are projected violently by the centrifugal force generated in the rapid rotation of the great drum. This ill-effect of the work seems to show itself even on the children of the workers in question; for while the mortality of children under five years of age is 49 in the general rural and urban population, it is 54 among the linen carders.

The accidents which were numerous before either the gearing or rolls were guarded, have become rare. They occur chiefly from cleaning machinery in motion. The views expressed by Mr. Boulin in relation to carding and other operations in the wool industry (see article "Woolen Manufacture") have equal force here.

Although hacking and carding are the worst, the preparing room is not free from danger. Purdon speaks of a mortality of 31.3 per cent. among those engaged in preparing, and Gilbert also found that the health of the women so employed left much to be desired. The fine dust, in large amount, easily penetrates into the respiratory tract to produce there the lesions described in the articles "Dust", "Occupational Diseases: Respiratory Tract", and "Tuberculosis".

The preparing rooms, being esteemed wrongly to be relatively healthy, are used by the management as rooms in which to place women who do not appear strong. These facts no doubt influence, on the one hand, the high morbidity rate in these workrooms and account, on the other, for the strong opposition raised by the employers to requests for the installation of fans for the removal of the dust in the manner required for the carding and hacking machines.

The accidents often caused in the cleaning of the machinery in motion are generally needle pricks from the gills and are not usually very serious.

In roving and dry spinning the trouble is much the same as in preparing and the situation the same; when spinning on high counts is in process, especially of low, plenty of fine dust is given off.

**Moist heat and humidity.** — Moist heat is the worst evil in the wet spinning rooms; humidity without excessive temperature in winding. As to the effect of "moist heat", see the article "Air: Hot and Humid Atmospheres".

Besides general ill-health, linen spinners suffer from local lesions. Lefebvre, of Lille, has described four forms of eczema of the hands amongst flax spinners, which in Belgium go by the name of wateranker. There is another form which, contrary to that first mentioned, does not cause pain; it consists in a kind of erosion of the epidermis, attacking some 50 per cent. of the spinners on the palmar aspect of the two hands. Lastly, mention should be made of small ulcerations bearing some resemblance to that caused among hide and skin workers. Are such lesions for the most part without danger, of microbial origin or not? This would appear impossible to assert definitely. They are most frequent among those spinning high counts, that is, where the water in the troughs is nearer 80° C. than 60°, and should be, therefore, sufficiently pasteurised. If not of microbial origin, then possibly they are due to the irritating action of the acids used (lactic or butyric acid), or to putrefying organic matter which accumulates in sufficiently large quantity in the water troughs.

The blow from the flyer causes a small callosity — characteristic sign of the trade — on the palm of the left hand of the spinner, situated on the hypothenar eminence, which occasionally becomes inflamed and even suppurates. Another callosity occurs on the palmar surface of the right index finger. There are also cases of retraction of the little finger. Lastly, a number of spinners have a little ulcer on the internal surface of the ankle due to the shock of the sabot on the softened tissues. Gilbert reports also cases of onychia of the big toe.

Cases of acne of the arms and face are also due to the action of oil similar to that common in the engineering industry. Such cases are reported also among spinners whose hands come into contact with warm solutions of sodium chloride, sulphates and other salts of calcium (Thieberg, Leloir).

The flax after wet spinning reaches the winding rooms saturated with moisture, which to some extent it loses
FLAX AND LINEN INDUSTRY

during the process. The air of these rooms, although there may be less dust, is more heavily charged with moisture, a fact perhaps explaining the high morbidity figure for rheumatism (0.51) and diseases of the respiratory tract (1.10). These workers stand at their work, and, in a number of factories, must keep their feet on a lever during the whole time the winding machine revolves. Although not hard work in itself, its continuous nature induces fatigue rapidly. Pathology in relation to work in the drying rooms comes under the article "Air: Hot and Humid Atmospheres".

HYGIENE

Retting the flax in water or on meadowland — operations generally carried out by the farmer — raises the same objections as those of retting hemp (see that article).

Retting should only be permitted in walled conduits and on specially prepared soil, such as marsh land. The channels are preferably constructed of masonry and the ground is cut away in such a manner as to avoid all chance of accumulations of flax in the corners and to facilitate cleanliness.

Retting is prohibited in public streams or public lakes.

The local authority may lay down conditions as to the flow, changing, the time retting shall continue before the water is changed, and as to the treatment of residues that may be harmful to fish.

The channel for water to be used for retting must during its entire length be constructed with walls and an imper- vious bottom, and it must be arranged in such a manner as not to constitute a nuisance on public health grounds.

The retting grounds must be situated some distance from habitations (at least 200 metres) — unless retting is done in running water — and at least fifty metres distant from isolated dwellings, wells, reservoirs, etc.

The plant is freed of its leaves before being placed in the channel. While the operation is being carried on, the plants must be submerged and the water changed as often as possible.

The waters and streams must be cleaned once or twice a year, and the residues must be destroyed or got rid of above ground.

If retting is done industrially by means of acid solutions, warm water, etc., there must be impermeable flooring, means for discharge of the water, incombustible material used in construction, isolation of the store rooms, drying rooms and furnaces, etc.; frequent

removal of the residues which can be utilised as manure, etc.; good ventilation, etc.

The scutching mills must be well ventilated. Dust must be burnt in the furnace flues or collected in dust chambers. The fires must be placed outside the workrooms, which must be lighted by means of enclosed lights. There must be steam heating; noise and vibration of the machinery must be prevented as far as possible.

Scutching comprises breaking, the object of which is to detach the boony tissue more easily from the fibres, and scutching properly so called serves still further to remove such bark as has not been got rid of by the preceding process. These operations, carried out either by hand or machinery, are so dusty that they require to be dealt with (happily a sufficiently easy matter) by capturing the dust at the point of origin by means of suitably applied local exhaust ventilation.

Each breaker must be fitted with a fan in such manner that no fine dust can escape into the atmosphere of the room. The exhaust piping leading from each breaker should be conveyed to a centrifugal fan by way of a main duct situated either above or below the machine (preferably the latter).

Downward exhaust ventilation is undoubtedly the best, for machines dealing with flax, hemp, etc.

Machine hackling rooms require to be dealt with similarly by locally applied exhaust ventilation over each machine, the air force and pressure being equally distributed as regards each working post. Provision of general mechanical ventilation only signifies removal of part of the dust after the worker has inhaled the rest (Leclerc de Puligny).

The amount of air removed should be 200-300 litres per machine, with an air velocity of 16 metres a second in the duct. The floating filaments drawn away by the fan should be separated by means of metallic filters or separators, baffling chambers, etc. Such apparatus naturally should be selected as, other things being equal, will cause the least resistance to the passage of air. The air discharged may advantageously be directed on to a water surface, the level of which is constantly maintained (Bellon).

In cold weather, when warming the air is necessary, the ventilating air should be recovered and after purification be returned to the room, without loss of heat.

Every carding machine should be covered by a sheet iron casing connected up with a fan revolving at such a velocity as to maintain a slight neg-
ative pressure, and prevent interference with the carding process or increase in waste products.

Another system is based on localised ventilation and removal of the dust to underground galleries of large size in which the detritus collects; this involves downward exhaust ventilation at a very low air velocity. While the dust is taken away by the fan, the fibres remain and are collected in trenches.

While preparation is going on prior to spinning, the fine dust given off can and ought to be, removed by localised exhaust ventilation, the more so as this offers no difficulty and requires only a slight negative pressure to secure good results (Frois). It should be assisted by slight humidification of the air.

In dry spinning which is relatively less important than wet, conditions can easily be improved by very slightly humidifying the air by a simple method of pulverising water. It is better not to employ the old methods of pulverising water under pressure, but rather to pulverise by means of compressed air playing through a nozzle fed by the water to be vaporised (Koerting and Lambert, etc.).

Theoretically a flax mill can be said to be good, so far as health matters are concerned, if the dust, caught at its point of origin, is carried directly to the outside in closed ducts, and if methods are adopted for lowering the temperature when this is too high, increasing it when it is too low, and diminishing where necessary the degree of humidity.

Each of these problems has been solved, and practice and experience are constantly at work to perfect the application of the solutions in question. To provide absolutely healthy conditions in a flax mill (and the same considerations apply also in the case of hemp and jute) is a very complex problem. In certain departments (hackling and carding) the need is to protect the workers against dust, because the rooms are generally very large, although the number employed may not be; hence the air is not vitiated by the products of respiration. In wet spinning rooms the air temperature and the humidity of the air have to be kept down. In dry spinning and preparing the dust is less abundant than in the departments of hackling and carding, but is still present in sufficient quantity to call for its removal. Further, the number of workers employed in the rooms, which are generally low roofed, requires sufficient artificial renewal of the air which, in cold weather, ought to be warmed.

The principles which should guide employers in the choice of the type of construction as well as the methods to be adopted for bettering the conditions of flax, hemp and jute mills, have been described in special articles (see especially "Air: Hot and Humid Atmospheres", "Dusts", "Air of the Workroom", "Ventilation", etc.).

The flax should begin to be humidified immediately after hacking, that is, as soon as it is carried into the warehouse, where 80 per cent. relative humidity should be maintained. In the preparing stage the best temperature is 18° to 20° C., with a relative humidity of 80 per cent.; for spinning a rather higher temperature (24° C.) is necessary, with a relative humidity of 80 per cent.

In weaving sheds a very high relative humidity is required, because the greater the humidity the better the conditions for weaving. A relative humidity of 80 per cent. is regarded as a minimum.

H. Neu thus sums up the temperatures and the minimum conditions which should be adopted for working under the best conditions in hemp, flax, jute, tow, phormium and ramie manipulation:

<table>
<thead>
<tr>
<th>Textile materials</th>
<th>Workrooms</th>
<th>Minimum temperature</th>
<th>Minimum relative humidity at the temperature named</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Degrees Centigrade</td>
<td>Per cent.</td>
</tr>
<tr>
<td>Linen</td>
<td>Warehouse</td>
<td>18</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Preparing</td>
<td>18</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Spinning</td>
<td>24</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Winding</td>
<td>18</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Weaving</td>
<td>18</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>of cloth on ordinary looms</td>
<td>18</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>of cloth on Jacquard looms</td>
<td>18</td>
<td>80</td>
</tr>
<tr>
<td>Tow</td>
<td>Mixing</td>
<td>18</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Preparing</td>
<td>18</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Spinning</td>
<td>24</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Winding</td>
<td>18</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Preparing</td>
<td>18</td>
<td>70</td>
</tr>
<tr>
<td>Jute, Hemp, Phormion and Ramie</td>
<td>Spinning</td>
<td>22</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Weaving</td>
<td>18</td>
<td>70</td>
</tr>
</tbody>
</table>

On the subject of bleaching with chlorine or hypochlorites, see the article "Bleaching."

The effluent after retting varies in composition. The effluent is dull, yellowish-grey in colour, with a disagreeable smell, very rich in organic matter and acids. It can only be allowed to leave the factory premises after having been subjected to neutralisation and purification. This treatment with milk of lime or lime and sulphate of alumina is applied, which eliminates 50 to 60 per cent. of the
organic matters. This process, however, is insufficient, but suffices to permit of the effluent being discharged into the sewers. It can only be passed into streams or rivers after biological treatment, subsequent to neutralisation, by means of slow filtration through sand containing nitrifying bacteria, or by automatic sprinkling over clinkers or coke of substantial thickness, or by distribution over the land, as on a sewage farm (see the article "Industrial Waste Waters").

Certain details in the management of linen factories require special attention; as for example the construction of cloakrooms.

In dusty workrooms, the clothing ought to be so placed that it cannot become soiled while it is not being worn. In wet spinning particularly the cloakrooms should be in a special room capable of being warmed in winter so as to prevent the workers having to put on wet clothing and so get chills on leaving the factory, where, while at work, they have been subjected to high temperatures.

Fatigue likely to be induced by defective lighting is less to be feared now that the length of the working day has been shortened, and with the present means of lighting, than it was when the hours were long and either gas or petroleum was in vogue for lighting purposes. On the other hand, electric lighting is not without effect and effort must be made to prevent the effects of glare and dark shadows.

The principal causes of accidents in each type of workroom have already been referred to. To these should be added blows from the flyers to the fingers of the weavers — very frequent, although not serious. In the wet spinning rooms, too, quite a number of accidents are due to falls on the wet floors from wearing sabots. Other accidents are not confined to the industry in question and belong to general prevention.

Legislation

Young persons under 14 years of age are prohibited from employment in Bel-gium in hackling, scutching, and spinning in rooms where dust is given off without being removed by mechanical ventilation. They are likewise excluded from retting carried out with the aid of chemical agents and mechanical apparatus.

Young persons under 18 years are excluded in France from scutching the dust is evolved, and spinning where satisfactory arrangements are not made to get rid of the water.

In the Netherlands male young persons under 16 and girls of less than 21 are excluded from hand scutching.

In Italy young persons under 21 are excluded from scutching, hackling, etc., when efficient exhaust ventilation is not provided.

In Spain boys under 16 and girls under 21 are excluded from cleaning, tow breaking, and carding if the dust is not removed by a fan, and from spinning, if means for removal of the water is not assured. See also article "Cotton".

It is desirable to encourage substitution of machinery for hand work, especially that performed by boys in hackling, even to making such substitution obligatory, and to raise the age of those employed on it to 14 or 16. In the case of women employed on carding, although their work is not so fatiguing, a limit to the age of admission should be fixed: in the case of both sexes it should not be less than 18 years, unless effective exhaust ventilation is provided for the machines (Burgeron).

Regulations for the processes of spinning and weaving flax and tow have been made in Great Britain, dated 26 February 1906. They require general ventilation in all rooms, taking as the standard the proportion of carbonic acid gas found. In no room must the proportion exceed 20 volumes per 10,000 volumes of air at any time when gas or oil is used for lighting, 12 volumes when electric light is used, or 9 volumes at any other time. The precise rooms are enumerated in which exhaust ventilation must be installed for the removal of dust as near as possible to its point of origin. In some cases care is even taken to specify the diameter of the exhaust ducts required, or the linear velocity of the draught passing through the piping. Temperature is not permitted to fall below 50° F. in hand hackling, roughing, or machine hackling rooms, and not below 55° F. where sorting, carding or preparing are carried on. No person employed must be exposed to a direct draught from any inlet or to any draught at a temperature of less than 50° F. In all rooms where these processes are carried on, an accurate thermometer must be kept. In every room in which wet spinning is carried on, or in which artificial humidity of air is produced, a set of standardised wet and dry bulb thermometers must be kept affixed in suitable places and maintained in correct working order. Each of the thermometers must be read twice a day, between 10 and 11 a.m., and 3 and 4 p.m. The results must be entered in a prescribed form placed near by, and forwarded monthly to the district inspector of factories: provided that this shall not apply to any room in which the difference of reading between the wet and dry bulb thermometers is never less than 4° F. If notice of intention to work on that system has been given to the inspector in prescribed form. The humidity of the atmosphere shall not at any time be such that the difference between the readings
of the wet and dry bulb thermometers is less than 2° F. The water used for producing humidity must be pure, that is, any water which absorbs from an acid solution of permanganate of potash in four hours at 60° F. more than 0.5 grain of oxygen per gallon of water shall be considered impure.

Efficient splash guards must be provided and maintained on all wet spinning frames and waterproof clothing provided for the women employed. Every wet spinning room must be kept in sound condition and drained so that every wet spinning room must be maintained in a sanitary condition. Cloak-rooms should be ventilated and heated when the temperature reading of the dry bulb thermometer exceeds by less than 2° F. that of the wet bulb thermometer.

France has no special regulations; but the provisions of the Decree of 10 July 1913 enable measures to be applied analogous to those in Great Britain.

The Netherlands requires obligatory notification of skin diseases (eczema and dermatitis), respiratory diseases, inflammation of the joints and sub-cutaneous cellular tissue among workers in linen factories.

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L. Bargeron
(Paris).

Flour Mills


TECHNICAL DATA

A modern flour mill comprises silos (see that article) for storage, of which each receives a particular kind of corn. Suction or pneumatic apparatus tends more and more to supplant the ordinary grain elevator.

The pipe line ends in a flexible joint with a aspirating nozzle which is plunged into the hold, to be emptied. The pipe line, which can be as long as 100 metres, is sometimes placed under, and sometimes above, ground. It is provided with a very simple arrangement allowing of a preliminary cleaning of the grain. The air, before entering the pump, is passed through filters which free it of almost all dust in suspension. The grain, before reaching the silos, passes through a bolter (revolving cylinders, shakers provided with powerful exhaust draught).

A distributor below each silo permits, by judicious dosage of the different kinds of corn, a flour to be obtained of the required richness and colour. Despite the first cleansing effected by the pipe line, not only are there still impurities (dust, etc.) but also barley, oats, and corn cockles, debris, etc. This is why up-to-date flour mills are equipped with very complete apparatus for cleaning and conditioning, which can be described as follows.

The first apparatus takes the form of a "separator" for sieving and aspirating, which holds back the foreign matter, eliminating the sand and small grain:

The "Carter separator" which sorts out the grains of oats, barley and corn cockles;

The "Kapak sorter", a perfect apparatus for sorting corn cockles and very small grains;

The "shaker" (épointeuse), in which, under strong exhaust ventilation, the corn is shaken violently and freed from all foreign matter before being despatched to the filters.

The last named is of a pressure type made up of a series of very closely knitted cloth bags, which keep back the dust and allow the air to pass through. The corn is then sent to be washed and conditioned. With this object it first passes into a washer, or to be more exact into a stone remover, the nature of which will be readily understood. It then passes through a centrifugal machine, afterwards going to the conditioner for a certain amount of moisture to be restored to the grain. Before passing to the crusher the corn is made to undergo a final cleaning either by brushing and aspiration or by using a special shaker (épointeuse). The grain then reaches a magnetic separator to rid it of metallic particles, and lastly a registering weighing machine.

To obtain the flour the corn is sent to the crusher and converter, the machinery of which is made to run according to the product desired. Sometimes plansifters are met with, which have now almost entirely replaced centrifugal
machines. A plansifter generally comprises two boxes, each of which contains a dozen sieves. To rid the silk sieves of gummy matter, soft bristle brushes are used on the upper surface of the sieves and coarse bristle ones on the lower.

A special mechanism gives a rotating motion to the sieves, which have a classifying or sorting purpose. Through these operations the separation of the bran and refuse is effected; then follows the sifting of the semolinas and meals.

The commonest type of sifter comprises a sloping sieve, an arrangement for ridding the silks of gummy matter, and a blower.

The flour then passes to the converter, to the centrifugal machine or to the plansifters, which are more and more coming into use, although the centrifugal machines give excellent results.

The flour and the waste go to the bagging machine which operates automatically, at the same time as the weighing.

It is well to bear in mind that modern technique has, by the introduction of auxiliary apparatus such as bucket elevators, helped very greatly the progressive development of mechanical transport.

STATISTICS

Recent data as to the morbidity of millers are relatively restricted. An enquiry by Kruger and Saupe, made in 1928 in German flour mills and bakehouses, pointed to an improvement in the sanitary conditions of the persons employed. According to another enquiry made between 1920 and 1922 in the flour mills of the State of Victoria by W. Summons, the medical examination of the workmen enabled the conclusion to be drawn that the pathological troubles were not frequent, and were never so serious as to cause incapacity for work.

Thus, of 157 workmen examined (of whom 119 were millers and 38 grain warehousemen), 16 were suffering from respiratory troubles, but 10 of them had not contracted the malady from their employment, 15 complained of digestive disturbance, but 9 of them were not attributable to their work; 8 were troubled with various ill-effects, such as sleeplessness (3); headache and deafness (2); paralysis (1); hernia (1); skin abscess (1). The flour mills in which the enquiry was conducted possessed a modern equipment installed in buildings several stories high, and all of them provided with numerous windows and adequate ventilation.

Similarly enquiries made by W. MacWhite in the flour mills of Western Australia showed that the incidence of illness among the millers was very low. Out of a staff of which the total years of service amounted to 798 years, the amount of lost time was three years. Cases of hay fever occurred, especially in men whose personal hygiene left much to be desired and. However, this affection seemed to be rather rare, as those who are predisposed to it cannot work for long in flour mills. Tendency to respiratory catarrh of the upper air passages was shown to be fairly frequent, especially among old workmen who had spent many years of their lives in flour mills. It was practically non-existent among comparatively new workers in well-equipped modern establishments. No case of pulmonary fibrosis or emphysema was found. Some of the workers complained of irritation of the eyes without, however, showing objective signs of conjunctivitis. Finally, among very few of the old employees arteriosclerosis, albuminuria and high arterial tension existed, suggesting that the profession of milling does not predispose particularly to cardiovascular and renal affections.

On the other hand, medical examination of 137 workmen conducted in 1927 in a Leningrad flour mill (Kulikow) revealed the frequency of respiratory affections, especially in the older men. The number of those who had worked for more than five years amounted to 55.7 per cent. Those with sound respiratory passages numbered 20 (18 per cent. of the total employed). Rhinitis was present in 68.5 per cent. of the total; pharyngitis in 42.5 per cent. and laryngitis in 35.5 per cent. Acute laryngitis was present in 13.3 per cent. of the cases of laryngitis, and the chronic form in 25.2 per cent. Catarhal oritits of wax in the external meatus, and chronic supplicative otitis, etc., reached altogether 56.35 per cent. of the workpeople examined.

So far as mortality is concerned, English statistics (1921-1923), published in 1927 by the Registrar-General, are fairly low.

PATHOLOGY

The conditions of work in flour mills and, consequently, the degree of risk which the work entails necessarily vary with the type of installation. Old premises—in which are situated wind and water mills—entail greater exertion on the part of the workman and expose him to greater danger than do the modern flour mills. The fixing of the wings of the windmill according to the direction of the wind, setting them going and stopping them, regulating their speed, etc., expose the workpeople to various accidents. So it is too with water mills, where the attention necessary for the maintenance of the wheels and blades, and often work in the water, involve considerable risk for the workman. Transport of the grain and flour is often carried out in a very primitive manner; bagging and discharging the contents, the transport of sacks of grain and flour, of which the
weight may be as much as 100 kg.; and, finally, the handling and dressing of the grindstones used to be, and still are, a possible source of illness and fatigue for the miller, especially in villages where the machinery is of a rudimentary character and where the number employed is reduced to a minimum.

Naturally, this sombre picture only refers to premises of a quite primitive nature in remote districts not yet industrialised, because conditions of work in modern factories are generally much better. Thus in modern flour mills where the transport of the grain and flour is carried out mechanically, all the heavy work which used to oppress the workman is abolished. Similarly, the risk of accidents which accompany machinery moved by wind or water does not exist in premises where it is driven by electricity or steam.

Among the operations considered to be most fraught with danger is the dressing of the millstones, which has to be done by very experienced workmen. In this work a great deal of dust is raised, entailing damage to the respiratory tract of the stonedressers: tuberculosis, emphysema, pneumonia (Hirt). The splinters which fly off during this work constitute a further source of accident (injuries, foreign bodies in the eye, etc.).

As early as 1866, Chevallier, in an interesting report, drew attention to the danger of explosion from flour dust when it falls like snow from the bolting mill into the store room. An explosion may also be caused when grinding is done with stones placed too close together, so causing a considerable rise in temperature, and the sparks produced by the friction of various foreign bodies in the flour against the stones can set fire to the dust. In modern installations this danger is considerably reduced, as the millstones are replaced by rollers of steel or porcelain. But the danger from static electricity and the presence of metallic debris in the flour is always present. Very interesting data are contained in the annual reports of the Chief Inspector of Factories in Great Britain (1926 and later) on the subject of the risk of explosion in flour mills. (See also article “Dusts”.)

During their work millers are exposed to the action of dusts given off in the course of various industrial operations (see also article “Dock Labourers”, for the researches of Middleton on grain dusts).

The dust from cereals differs from that of flour by the fact that it contains, in greater or less quantity, impurities represented by solid particles, often sharp and jagged, of organic or inorganic matter: fragments of earth and of millstone, iron, straw, husk, etc.

These particles, especially those coming from the bales of oats exert an irritating action on the respiratory passages.

L. Ferrannini studied in 1912 the action of flour inhaled by millers. Although flour is generally considered to be innocuous to the respiratory tract, nevertheless there are writers, especially in past times, who have considered it to be the cause of broncho-pulmonary troubles. Thus, for example, Ramazzini speaks of cough, asthma and anaemia which he found among millers; Hirt, of respiratory affections; Ascher, of broncho-pulmonary lesions; Seiffert, of nasal and pharyngeal lesions; Schuster, of the frequency of pulmonary tuberculosis; Muller, of lesions analogous to those due to pneumoconioses, etc.

In dogs kept for several months in a very dusty flour mill, Ferrannini could not prove clinically and chemically the presence of starch except at the entrance to the upper air passages.

In about half of the flour millers whom he examined he found, on the other hand, a more or less important reduction in the respiratory capacity. Ferrannini is of opinion that the inhalation of flour is often inoffensive to the deeper respiratory passages, as the elements of the starch are capable of being partially digested.

But under special conditions (presence of enormous quantities of flour dust, lessened resistance of the respiratory passages, presence of other substances, etc.), it is possible for this dust to remain, wholly or partially, unchanged in the deeper respiratory passages and to set up there an obstacle to the bronchial tubes and alveoli of the lungs, with reduction thus of the respiratory surface and diminution of the vital capacity.

The presence of starch and albumin in the saliva of persons exposed to the inhalation of flour can be easily demonstrated.

Some persons with a natural predisposition have attacks of coughing and sneezing, which recall the asthma of hay fever (anaphylaxis). The irritation of the respiratory passages may terminate by inducing bronchitis, with a tendency for it to become chronic and associated with pulmonary emphysema.

Acute pneumonia has been observed, especially among flour millers work-
ing in water mills, where, during the cold season, they may contract chills. Pasteur Vallery-Radot and P. Giraud described (1928) an affection among workers who shovelled barley in a small French malting house. It was due to infection of the bronchi with Aspergillus fumigatus and Mucor mucedo, mushrooms which were present in considerable quantity on the grains of barley. This affection was described by the authors under the name of "Summer sporomycosis in grain shovellers", and it is rather common. The local and general symptoms present were due to the presence of a considerable number of spores in the respiratory tract, as well as, probably, to the absorption of toxic substances given off from the mushrooms.

A case of pulmonary amylosis was described for the first time by Gerhardt. Lowy has found that in small flour mills where conditions are bad, cases of ergotism (Morbis rurals) are also to be discovered. According to Krüger and Saupe (1928) respiratory troubles are most frequently complained of, and they are more pronounced among millers than bakers, which is accounted for by inhalation either of the flour dust or of particles coming from millstones, coal or ashes. The manifestations of rheumatism are frequent, also flat foot — "genu valgum" or "varum", etc.

In modern flour mills the unpleasantness caused by dust is very much diminished by the use of closed apparatus and arrangements for locally applied exhaust ventilation. The digestive disturbance observed in millers is attributed to swallowing dusts — notably flour dust which, containing crude starch difficult to digest, might very well set up an irritation of the gastric mucous membrane with anorexia and a tendency to cause wasting. Dental defects have been described in millers (Oldenborg, Krüger and Saupe), but their frequency is far less than it is among bakers and confectioners.

A diminution in hearing among millers is brought about by the plugs of wax in the external auditory meatus which are composed of deposits of fat, the dusts of cereals (particularly of oats) or flour cause conjunctivitis or ciliary blepharitis (Ramazzini and Hirt).

Millers often suffer from skin eruption, especially on the hands and forearms. They take the form of erythema or of eruptions resembling urticaria, with a tendency to the formation of rhagades. The different impurities present in the dusts occasion infections of the skin with the formation of boils, acne, whitlows and even of phlegmonous erysipelas. As in the case of bakers, millers may have what is called "bakers' itch", which is not due to an acarus. Old millers often have a millers' itch consisting of blackish grey spots on the dorsal surface of the first phalanges of the fingers and sometimes on the back of the hand and radial slope of the forearm. These spots are due to the penetration of the fragments of steel and stone during the polishing of the millstones. Blaschko has also described an analogous "itch" localized on the dorsal region of the hands and due to impregnation of the epidermis with the particles of iron and other splinters produced in the dressing of the stones.

In 1829 a report on the occurrence of cases of dermatitis among the weighers of grain in Nantes and Bordeaux, due to the presence in the grain of an acarus, was presented to the Health Council of Nantes. In 1886 similar cases were observed at Toulouse, the site of the lesions being upon the sides of the neck which was explained by the practice of carrying the sacks on the shoulder and so exposing the skin to direct contact with the corn and flour. Such cases are constantly occurring, and medical literature contains a number of important references, because this lesion attacks agricultural labourers, often in epidemic form, dockers, etc. — in a word, all those who are brought into contact with corn, flour, or sacks contaminated with the corn parasites.

In Great Britain, Bridge found (1926) similar lesions among persons employed in a malt house. According to Butler, of the Imperial Institute of Mycology, the parasite was Rhizopus nigricans. Marcandier and Le Chuitton described in 1928 the presence of Tyrolyphus farinace of Geer in corn of Russian origin as occasioning respiratory trouble in workmen engaged in handling it.

It should be added that certain risks attend the use of hydrocyanic acid gas for the destruction of maggots in flour when used improperly. The danger of poisoning can be easily prevented by carrying out the disinfection of the sacks in special places. Similarly, bleaching the flour with sulphur dioxide or chlorine containing chloride of nitro-syle (0.5 per cent) may be a source of risk to the workmen if they are not provided with breathing apparatus and proper goggles. In Great Britain (1922) ten cases of poisoning from this source were reported, the cause being gener-
ally attributed to defects in the plant, to accident or to negligence.

**HYGIENE**

Preventive measures must follow the lines of improvement in the hygienic conditions of workplaces, the plant and personal hygiene.

The most important thing is to take the necessary measures for the suppression of dust, which constitutes a principal source of risk to the millers. The perfecting of the plant in modern factories has gone far to comply with this requirement. Washing and bath accommodation are of importance, as offering opportunity to keep the skin clean and thus avoid the various skin burns.

Adequate measures require to be taken: for the prevention of accidents, for the abolition as far as possible of hand labour, for placing the workman out of the reach of danger as far as possible from work where use of poisonous gases (prussic acid, chlorine, sulphur dioxide), etc., is called for. Such work should be done in special chambers, at any rate under conditions of good ventilation; workpeople should be provided with efficient breathing apparatus. Risks of fires and how to prevent them and dust explosions must be considered (see article "Dust").

**LEGISLATION**

In Greece employment of boys under sixteen years of age and of girls less than eighteen is prohibited in flour mills where dust is given off in the workrooms; in Belgium young persons under sixteen years of age are prohibited from handling or mixing, on a large scale, vegetable matters when they give rise to injurious dust, etc. In the Netherlands compulsory notification is required in the case of pulmonary affections among millers and persons employed in cleaning or winnowing corn. Phtisis among millers is subject to compensation under the 'Queensland Legislation.

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Fluorine and Hydrofluoric Acid

Fluorine (symbol, F; specific gravity, 1.865) is a greenish yellow gas with a very irritating smell. It is obtained by treating calcium fluoride with sulphuric acid. Fluorine ignites bromine, iodine, sulphur, crystallised silicon, alkaline metals and a large number of organic substances (benzine, alcohol). It explodes with hydrogen and attacks chlorides, bromides and iodides. It decomposes water with production of ozone and hydrofluoric acid.

Submitted to a temperature of —250° C, it becomes solid and white; fuses then at —233° C. and boils at —187° C. From the hygienic point of view fluorine does not often play a direct role because in the atmosphere it becomes converted into hydrofluoric acid.

Hydrofluoric acid (HF or H₂F₄) results from the action of fluorine on water. Fluorine, in the presence of the aqueous vapour in the atmosphere, becomes converted immediately into hydrofluoric acid — liquid solidifying at —92.3° C. and boiling at 19.5° C. Its specific gravity is 0.979 at 12.5° C. (Moissien). Hydrofluoric acid dissolves in water, for which it has a marked affinity. The commercial acid is a solution of hydrofluoric acid in water.

The majority of metals decompose the acid combining with the fluorine and setting free the hydrogen.

The most characteristic property of hydrofluoric acid is that of dissolving and attacking glass, because it acts energetically on silicon, with which it forms fluoride of silicon and water. Fluosilicic acid (H₂SiF₆) does not attack dry glass. Thus it is that in industries giving off fluorine the atmosphere contains definitely hydrofluoric acid and often fluoride of silicon (SiF₄), especially in the manufacture of aluminium, when, for electrolysis, coal containing an abundance of silica is used), and this in contact with water vapour yields fluosilicic acid.
Hydrofluoric acid is conveyed in barrels tarred inside, or else in metal receptacles with a leaden bung. Lead or gutta percha bottles are used for small quantities.

**Use**

Hydrofluoric acid is used especially for etching on glass, crystal, metals, etc. Generally a mixture ("white acid") of hydrofluoric acid is used with other substances having for their object to delay or accelerate the corrosive action on glass. The ink used to write on glass has for its base ammonium fluoride. Etching on glass, by means of hydrofluoric acid, is effected either with a watery solution or with the acid vapours. In the former the part etched remains clear and transparent; in the latter it is rendered opaque. The glass to be etched is first covered with a thin protective layer of wax, a special varnish which is removed at the portions where the effect on the glass is to be produced. The object is then plunged into the solution of hydrofluoric acid or into a mixture of sulphuric acid and potassium fluoride gently heated by a small flame. The protective coat is gently removed by means of spirits of turpentine or alcohol, or some other solvent according to the nature of the protective coat employed, and the engraved drawing appears on the glass, the protected portions remaining intact.

Hydrofluoric acid is also used in industries conducting fermenting processes and the distillation of certain beverages to prevent secondary fermentations injurious to alcoholic fermentation (e.g. in brewing); in the manufacture of fluorides of antimony; as a substitute for tartar emetic in dyeing under the designation of "salt of antimony"; etc. Hydrofluoric acid is evolved with fluosilicic acid in the superphosphate industry (decomposition of phosphorites by sulphuric acid), and also in the production of phosphorus by treating the bones with sulphuric acid, in the lucifer match industry, and in making inflammable articles; in the production of peroxide of hydrogen, and especially in the manufacture of aluminium by electrolyzing alumina in a bath of cryolite melted at a high temperature. Fluosilicic acid and its salts are principally employed as antiseptics in the treatment of skins; they are also used as reagents in chemical laboratories. Their use has been proposed in the sugar and spirit industry to precipitate salts of potassium and also as a mordant in dyeing.

Fluosilicate of sodium is used in the manufacture of opaque glass and precious stones. Further, disguised in various ways, the fluosilicates are sold as specialties for the preservation of foodstuffs, notably to preserve and disinfect beers (as a protection against secondary fermentations), wines, etc.

**Toxicity**

Fluorine can exercise a local and general action upon the organism in different ways.

Hydrofluoric acid has a local caustic action as has also fluosilicic acid.

Its general action depends for the most part on the ingestion of the acid or its salts.

So far as local action is concerned for the same doses of fluorine, there is a great difference in its action on the dry skin and that on the moist mucous membranes; in fact, in presence of water fluorine immediately forms very active hydrofluoric acid.

When strong concentrations act on the skin, the lesions take on the character of a dermatitis of variable form — often with formation of vesicles, and in the most advanced stages of necroses and ulcerations, these becoming indurated and difficult to heal.

On the mucous membrane irritant and inflammatory effects become manifest, resulting eventually, in the case of inhalation of concentrated vapours, in torpid slow ulceration of the nasal mucous membrane, the gums, larynx, bronchi and conjunctivae.

Inhalation of small doses of hydrofluoric acid causes less serious lesions; but even in weak concentrations, such as have been tried therapeutically (0.02 per cent.) they are capable of setting up irritation of the nasal mucous membrane with lachrymation and salivation.

It would appear, however, as though really the system of those coming constantly into contact with fluorine underwent some kind of adaptation. Experience indeed shows that workpeople seem to be relatively immune to tuberculosis, and this has given rise to the idea that this substance might be valuable therapeutically.

Trouble has arisen from ingestion either of solution of hydrofluoric acid in water or salts of fluorine.

**Fluosilicic acid** and its salts act in an analogous manner; according to Wieland and Kurtzahn, the fluorides and fluosilicates have a toxicity corresponding with the quantity of fluorine contained per unit of weight.

These same observers have noted in regard to fluosilicic compounds how
feeble is their power of dissociation and the high content of undissociated molecules of hydrofluoric acid which make fluosilicic acid a powerful caustic poison.

Beside the acid salts of fluorine must be placed the alkaline salts — notably the fluorides and fluosilicates — which are also able to exert analogous action on direct contact (although less energetically than acids).

The direct action of salts of concentrated fluorine in solution is, as in the case of acids of fluorine, a caustic and irritating one which is exercised indeed in relatively feeble concentrations: the skin is fairly resistant, but the mucous membranes may be sensitive to solutions of as low a concentration as 1/2 per cent.

So far as general action is concerned compounds of fluorine, absorbed through the digestive tract, produce poisoning of the same kind as if received subcutaneously or intravenously. Ingestion of fluorine salts in large amount gives rise to acute poisoning with rapid fatal termination. This is also the case with injections, or, where the dose is not fatal, local necrosis frequently ensues.

Generally the toxic symptoms following on direct introduction of these salts into the body are vomiting, cramps, muscular paralysis, preceded by fibrillary tremors, and rigidity; acceleration at one, followed by paralysis, of respiration, paralysis of the central nervous system; other symptoms of less importance also occur. Death supervenes from respiratory paralysis with the heart in diastole.

Recent experiments enable a fairly accurate figure to be given for the average dose necessary to produce a fatal result; in the case of laboratory animals, 0.05 centigrams per kilo body weight given by way of the intestinal tract and 0.10 to 0.15 given intravenously would induce rapid death. Often, however, a very much smaller dose suffices.

In man cases of acute intoxication, still exceptional ten years ago, are now quite numerous; this increase is accounted for by the commercial use of fluorides and alkaline fluosilicates or of mixtures of fluorides with other substances. These products are intended as food preservatives or as vermicides.

The fatal dose for man varies: in the literature on the subject a fatal issue has been recorded with a minimum of 6 to 10 grms. But again recoveries are recorded after ingestions of 30 to 50 grms.; clearly appreciable quantities of the toxic substance are sometimes rejected soon after ingestion. Non-fatal poisoning has often been described as a result of accidentally swallowing different quantities in mistake for medicine or common articles, and even after eating cake made from baking powder containing fluorine. Powders made up with phosphates from apatite, which is a phosphate of lime with fluorine or chlorine (fluorapatite and chlorapatite). In man, absorption of quite small amounts (fractions of a gramme) can set up all sorts of symptoms — nausea and vomiting, gastric pain, salivation, pruritis, dysuria, diarrhoea. With more than one gramme these symptoms increase in severity, and weakness of the heart, respiratory distress and derangement of the kidneys may supervene.

How hydrofluoric acid acts has been much discussed and comparing the effects of this acid with those of oxalic acid the general conclusion is that it is due, at least partially, to the power fluorine has of fixing the lime of the juices and tissues in a form which is said to represent an almost fixed stable condition of calcium, rendering it afterwards practically unfit for use by the organism.

Some writers do not think it necessary, in determining the action of fluorine, to have recourse to such suppositions or indeed to regard it as having any special toxic action. This interpretation, however, is not accepted by everyone. Really, several facts tend to confirm the opinion that fluorine has special toxicity, notably the fact that lower organisms deprived of lime are in spite of this attacked by fluorides, but not by oxalates.

Cristiani and Gautier insist on the fact that a part of the fluorine ingested is retained by the organism — a thing easy to understand in taking into consideration the formation of calcium fluoride and the difficulty in eliminating it. It is possible therefore to understand, at least partly, the caæsæ of the experimental fluoric cachexia which has been described; a fatal affection, making its appearance at times quite early in animals subjected to a fluoric diet, and at others coming on later (after several years) if very small doses are administered. In animals a constant fixation of gases on forming "calcium content" of the tissues and juices and at the same time an accumulation, more or less diffuse, of calcium fluoride in certain tissues.

Recent experiments carried out to study the effects of emanations in aluminium factories by Cristiani and his collaborators, have brought many new facts to light showing, on the one
hand, the injurious action of small repeated doses of fluorine and alkaline fluorides and explaining on the other why this chronic deleterious action is so little known. Really the manifestations are late and the poisoned animals can live quite a long time without exhibiting any marked symptoms. The terminal fatal cachexia has no very special symptoms and death often comes on rather late with signs of bulbar lesions especially affecting respiration.

On the other hand it is neither certain nor probable that such doses of fluorine as are inhaled (following on exposure more or less prolonged in an atmosphere slightly charged with fluorine vapour) could bring about severe forms of chronic poisoning. In regard to this point Cristiani insists on the importance of ingestion as the main channel of absorption of the poison in the affection which he has described under the name of “fluorosis or fluoric cachexia” because fluorine gas, absorbed through the respiratory tract, is retained largely by the mucous membranes of the upper air passages to which it adheres. It is then eliminated or swallowed.

For long experts have been concerned with the emanations which, discharged continually by certain factories into the atmosphere, are said to exercise on the neighbourhood a seriously destructive influence on vegetation and cattle. In the case of animals this effect is the practical consequence of the damage inflicted on the plants. The animals really suffer from fluorine intoxication indirectly by consuming the forage which has been attacked by the emanations. According to Ost, the destruction referred to hydrofluoric acid exceeds by far that caused by sulphurous acid. The researches of Cristiani and Gautier enable the assertion to be made that fluorine is a substance of greater toxicity than sulphurous acid and offering greater risks, now better understood, and risks more immediate even than those presented by commoner emanations. The destructive influence shows itself also as a result of the repeated action of very small successive doses; the plants fix the injurious substance in the measure of contact with the exposed parts so that the damage can remain at first unseen and does not become apparent until the necessary quantity has accumulated. Humidity favours the action of the toxic gases and experience shows that solutions of fluorides or alkaline fluorosilicates attack vegetables very actively even when highly diluted.

Only a limited number of statistical data are available, very often confused with those of mineral acids. The death of the Belgian chemist Longuet has been caused by hydrofluoric acid in the course of his researches on the isolation of fluorine (Kohn Abrest). Inspector’s reports refer to respiratory trouble in a factory for the manufacture of fluorine (Prussia, 1900); in another factory the vapour was so strong that all the windows up to a height of 6 metres were attacked by the acid. In some cases medical examination showed that the mucous membranes were seriously affected (superphosphate manufacture). Statistics of the Swiss Insurance Office against Accidents give the following figures: 1915, 2; 1916, 14; 1918, 1 (included with cases due to mineral acids). In Austria several cases of dermatitis (1914-1918) were reported in glass factories. In 1931 a case was reported in Germany affecting a workman in a walking-stick factory who had to remove the silicic acid from the wood by means of a rubber sponge dipped in very strong hydrofluoric acid. In 1924, W. Roth described a dozen fatal cases, besides several severe intoxications, from the use of silicic acid as an insecticide and desinfectant agent. Boulin in France has narrated how the hydrofluoric acid vapours given off from a factory removed the polish from the windows at a distance of 2 kilometres.

To-day, however, the damage from hydrofluoric acid is generally limited to the production of a more or less severe dermatitis, localised chiefly on the hands, face, mucous membranes of the nose, eyes and mouth, and more rarely on the upper air passages (chemical industry, manufacture of hydrofluoric acid and its compounds, aluminium works, glass works, dyeing and bleaching, artificial manure, extraction of silicates, laboratory work, pottery manufacture, etc.).

Examination for and estimation of fluorine are more difficult and more liable to error than is analysis of the majority of other mineral substances. Examination for fluorine is laborious because of the difficulty of setting it free and fixing it before it has combined with other bodies in the matter to be analysed.

Use is made of its property of attacking glass and the quantity of fluorides present is judged by the intensity of the corrosive action on glass. For practical purposes it is enough to examine the state of the panes of glass in the windows either of the factory or neighbouring houses to determine pretty readily the presence of hydrofluoric vapours.

All contact with the acid solution should as far as possible be avoided.
by use of tools, wearing of gloves and application of ointment (lanoline, vaseline on the hands). Handwork should be reduced as far as possible. The fumes should be removed as near to the point of origin as possible by means of locally-applied exhaust ventilation. In glass etching use of hydrofluoric acid is now often replaced by sand blasting. Crushing raw material in the manufacture of superphosphate (see that article) should be done with the precautions there indicated. When the vapours cannot be caught at the point of origin, mechanical ventilation should be arranged in such wise as to direct them, into chambers or towers where they can be neutralised. The ventilation apparatus should be of acid resisting material. The fluorides should be recovered eventually. Baths of hydrofluoric acid should be hooded and good general ventilation arranged for.

So far as glass etching is concerned a mixture has been recommended less rich in acid and richer in neutral compounds. A neutral substance, soluble in water, has also been suggested, use of which would practically suppress evolution of acid vapours and which is yet reputed to have, at the same time, excellent etching properties. Any person who has inhaled concentrated hydrofluoric vapours should be removed quickly and first aid, as in the case of acids, administered.

Compresses of acetate of ammonium are advised as treatment for burns on the skin and an ammoniacal application (although it is painful) to neutralise action of the acid that may have penetrated under the nails.

**LEGISLATION**

Women are prohibited from work in the manufacture of hydrofluoric acid or in work exposing them to hydrofluoric vapours in France, Japan, and Switzerland. Young persons under 18 years of age are prohibited from similar work in the Netherlands and in Switzerland; boys under 15 in Italy and Japan and under 16 in Belgium and Spain; women under 21 in Belgium, Italy, Japan, and Spain.

The prohibition applies generally to etching on glass by means of hydrofluoric acid fumes.

Obligatory notification of injury caused by fluorine and hydrofluoric acid is required in the Netherlands; and compensation by Japanese and Swiss legislation.

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**Food of the Industrial Worker**

French: Alimentation du travailleur indus-
driel. — German: Ernährung des indus-
triellen Arbeiter. — Italian: Alimen-
tazione dell'operaio. — Spanish: Alimen-
tacion del obrero.

The body of man may be likened to a machine in that it derives the energy required for the performance of external muscular work from the oxidation of the food ingested, just as the locomotive derives the energy which drives it from the combustion of coal. But the analogy stops at this stage because the body utilises the foodstuffs not only as fuel but for other physiological processes, such as the repair of tissue wear and tear and growth. In other words, the working parts of the human organism are composed of like materials to those ingested as food.

A well-balanced diet capable of maintain-
ing man in health and vigour must contain a number of materials differing widely both in chemical structure and in physiological function.

There are at the present moment regarded as alimentary substances mate-
rial serving to build up the tissue or to repair tissue wear and tear and mate-
rial which enters into combustion with oxygen and produces the energy essen-
tial to the maintenance of life. Many substances serve to constitute a reserve 
deposited in the tissues which is only utilised by the organism after consider-
able delay.

It is customary to divide these mate-
rials into two groups. Group A con-
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sists of the foodstuffs which not only are essential for tissue functioning but are the sources of the energy required. Group B consists of substances which are essential to the life of the organism, but which, so far as is known, play no direct part as fuel.

Group A : Proteins, Carbohydrates, Fats.

Group B : Mineral Salts, Accessory Substances, Water.

Group A

Proteins

These are a special class of substances which are necessary in all diets. They are characterised by containing nitrogen and, as a rule, sulphur. They form the principle constituent of substances like lean meat, white of egg, etc. The food proteins are derived from both animal and vegetable sources. They have a most complex structure, the constituent elements or “building stones” being amino acids.

They represent the ideal nutritive substance which has no substitute, while they may to a certain extent replace other elements. Complex alimentary products may be estimated in proportion to their nitrogen content and the quantity of albumin is calculated by multiplying the weight of nitrogen found by 6.25 (that is to say, when the protein substance in question contains 16 per cent. of nitrogen). The content of the compound elements in proteins is extremely variable: beef contains 17 to 21 per cent.; horseflesh, 21 per cent.; certain fish, 20 per cent.; milk, 4 per cent.; flour, 2 per cent.; cheese, 25-35 per cent.; cereals, 11-12 per cent.; vegetable products, 25 per cent.; etc.

The daily amount of protein substances consumed are derived therefore from the two sources; animal and vegetable. But are these of the same value from a nutritive point of view? The immediate answer is no. The vegetable protein has a lower consumption utility coefficient than the corresponding animal substances: 85 per cent., as compared with 95-97 per cent. for gastro-intestinal absorption for the latter. The fact receives confirmation in practice since with increased consumption of animal protein in the diet the vegetable protein does not decrease in proportion, but very much more considerably. On the other hand when wages permit of improved diet, workers at once increase the quantity of animal albumin consumed, the substitution in the quantity of vegetable albumin being greatly superior to the increase of animal albumin.

Carbohydrates

These are the starchy and sugary foodstuffs relatively simple in structure. They are fairly abundant in milk but, after infancy, man obtains the bulk of his supply from vegetable sources.

These compounds cannot be utilised except after transformation into glucose. Vegetable cereals contain 50-80 per cent. of amylopectin substances.

Fats

The fatty materials ordinarily used for human food are obtained from both animal and vegetable sources. They are somewhat more complex in structure than the carbohydrates, and have a histogenetic rôle. All such foodstuffs contain fats: meat, 15-25 per 1,000; pork alone, 50 per 1,000; cow’s milk, 40 per 1,000; cheese, 250 per 1,000; yoke of eggs, 300 per 1,000; vegetable products, about 20 per 1,000; almonds and nuts, 500-600 per 1,000; etc.

Group B

Mineral Salts

The body requires an adequate supply of sodium, potassium, calcium, magnes-ium, chlorine, sulphur, phosphorus, and, in addition, traces of other inorganic materials like iodine and iron. Man’s customary diet generally contains a sufficient supply of all these salts except sodium.

The majority of these salts are provided by foodstuffs of vegetable origin. The salts fulfil a plastic and a functional rôle. They ensure the balance and variations of the osmotic tension between the tissues and the liquids of the organism, favour the diastasic actions, the dissolution of protein substances, the function of the contractile tissues, and the activity of the endocrine glands, etc.

Water

It is obvious that an ample supply of water is essential, for more than half the weight of the body is made up of water and water is constantly being given off by the lungs and skin and in the excreta.

Other Substances

Human food finally comprises other substances used because of their exciting effect on the nerves and the senses of smell and taste, and which favour secretion of the digestive juices: alcoholic drinks (wine, beer, cider, etc.) with an
alcohol content varying between 3 and 10 per cent.

Drinks containing caffeine or other similar alkaloids (coffee, maté, tea, kola, etc.), the condiments properly so called (aromatic products, pepper, salt, and alliaceous products), etc.; honey and sugar are, however, proper foodstuffs.

Accessory Substances or Vitamins

There are three of these substances now recognised, although not yet isolated: fat soluble A, water soluble B, and water soluble C. The A substance is believed to play an important part in growth, B and C seem to be necessary for the maintenance of health. They are present in many animal and vegetable foods.

There should finally be recalled oxygen from the atmospheric air (about 700 grm.) necessary for burning the food ration.

Such then are the materials which when properly balanced form an adequate diet. The problem of the adequate diet may be discussed either from the qualitative or quantitative point of view. These two aspects although they may be dealt with separately are not in actual fact separable as physiological processes.

Quality

The quality of the food supplied, although it plays an all-important rôle in the nutrition of man, can only be briefly considered here.

The quality of a protein, so far as its value to the organism goes, would seem to depend on the number and kind of the constituent amino acids — building stones present in the molecule. Physiologically proteins may be divided into three categories: (a) perfect, (b) imperfect, and (c) defective, depending on whether the molecule contains: (a) all the essential amino acids in proper proportion, (b) all the essential amino acids but not in right proportion, and (c) lacks one or more of the essential amino acids. Obviously, a diet in which defective protein is the only protein present can never be a good diet. Where imperfect protein is the chief protein present, then it may have to be consumed in excess amount to yield a sufficient supply of some essential amino acid. As a matter of fact, the daily consumption of even a small amount of animal protein, like meat, generally ensures the adequate supply of the essential building stones.

From the fact that the cells of the organism consist of protein substances, it was deduced that protein formed the most important and irreplaceable element in the food ration.

The opinion of Liebig, according to which protein provides not only the means of repairing the wear and tear of the tissues due to their function but also the energy necessary for muscular work, has been disproved by the classic experiment of Fisch and Wislicenus.

This experiment has been made the basis of further research, leading to the conclusion that during muscular work the consumption of oxygen and the production of carbon dioxide are increased, and that these reactions are exactly brought about by the intermediary of organic products the molecule of which does not contain nitrogen. It is sugar amongst the nitrogenous substances which lends powerful assistance in the execution of muscular work and which consequently constitutes the most important source thereof.

The proteins certainly play a part in muscular work, especially in the case of work demanding excessive effort or when the food ration is deficient in carbohydrates.

On the basis of Liebig's theory, the physiologists had estimated that the daily quantity of protein required for a man of 60-70 kg. while at rest or engaged in light work should be 130 grm. (Moleschott) and that in no case should this amount fall below 118 grm. (Institute of Physiology, Munich).

It was Chittenden, of New York, who first demonstrated the exaggerated value of a gramme of protein per kilogram of body weight, and who proved that a value of 0.75-0.80 per kg. and per diem is sufficient. His research was effected in relation to several individuals with diverse living conditions and was followed up for over a year.

While, however, the food ration may contain a quantity of protein under the 118 grm. fixed by Voit, especially when the sugar and fats are present in sufficient quantity to satisfy the demands of the organism, it is difficult to accept without reserve the conclusions of Chittenden and the other experts.

According to Pugliese, it is not possible to fix a physiological minimum of protein in a diet, but it is, on the other hand, necessary to fix limits within which the daily quantity of protein may vary for a man engaged on a given type of work or at rest.

If there be taken into consideration the values suggested by Pflügge, Atwater, Slosse, etc., that is to say, 1.15-1.50 grm. of protein per kilogram and per diem for a man at rest, and 1.90-2.45 grm. for a man at work, it will be easily seen that the daily quantity for a man
Weighing 65 kg, will be from 75-100 grm. if he is resting and 125-160 grm. if he is working. An enquiry effected by Pugliese in 1915 and during the course of which he was able to study the alimentation of six healthy men, each of whom was engaged on a very different type of work, led to the conclusion that 100 grm. of protein in the daily food ration was excessive for an individual without occupation, sufficient for persons engaged on moderate work, but insufficient for those engaged on tiring work, not however demanding excessive effort.

The problem of alimentation of the industrial worker in Japan has recently been studied (1925) by J. Shimazono. One of the characteristics of industrial organisation in Japan is that the majority of women workers (89 per cent.) live in dormitories, installed at the expense of the factory. In consequence the food problem for these masses of workers represents a practical problem of first-rate importance. The food provided in many factories has an average value of upwards of 2,000 calories and contains about 50 grm. of protein per day. For young women weighing about 40 kgm. such a food ration amounts to 50 calories and a little over a gramme of protein per kilogram and per diem. This quantity might be sufficient for foremen and forewomen engaged in supervision in the textile industry, but the quality provided is not adequate even for these. Shimazono engaged in research in relation to this type of food and proved that it is poor in proteins and B vitamins. Such insufficiency is all the more serious since the workers in question are young girls of growing age.

There is little or no scientific evidence yet available to support the popular belief that an ample supply of meat is necessary in the diet of those engaged in heavy work and the question has been studied by the 1910 enquiry, 483 grm. as against 554 grm. 1

In the majority of cases the potential energy derived does not correspond to the demands of heavy work. In fact at Malines in 1923, only 164 workers consumed a ration appropriate for heavy work, whilst the total number of persons engaged was 464. For very heavy work, food is usually consumed in favorable quantities furnishing energy in harmony with the occupation. Nevertheless it is seen here, as is usually the case, that the food ration is by no means always dominated by the physiological exigencies of the work furnished. The worker of Malines, like workers elsewhere, does not of course regulate his diet according to the nutritive value of the foodstuffs which he can obtain for a given sum of money. The total proportion of workers who sought upwards of 20 per cent. of the proteins consumed in a meat diet was considerably higher in 1923 than in 1910, and, inversely, the proportion of cases in which 50 per cent. of the proteins was furnished by bread was greatly inferior to that of 1910.

Lambing drew attention to the fact that the quantity of proteins consumed amongst the population of Europe is higher than the minimum ration essential for obtaining experimentally the nitrogen balance, where vigorous races are in question, whilst a poor nitrogen balance, where vigorous races are in question, generally corresponds to poverty-stricken social classes or groups with only mediocre resistance.

According to a recent study (1925) by Rubner, the consumption in grammes of foodstuffs in the different countries and the corresponding amount expressed in calories is as follows:

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1 It is necessary to avoid the error of identifying all animal proteins with meat. It is true that a diet consisting of an undue large proportion of flesh is liable to injure the constitution especially in the case of individuals predisposed to digestive disorders. The solution of problems of a general nature must not, however, be sought in particular cases, which are more often the exception than the rule, the pathological rather than the physiological phenomenon (Pugliese).
The great bulk of the reserve store of energy in the body is laid down in the form of fat, which has a high fuel value in proportion to its weight. There is but little evidence to show how fat plays its part in yielding energy for muscular work, but it is very clear from experience that when hard and prolonged muscular work is to be done the presence of a relatively abundant supply of fat in the diet is desirable.

As regards the supply of salts, but little attention need be paid to the salt content of the food consumed. Salts are essential for tissue function. They play a predominant role in the acid base equilibrium of the body fluids.

Modern work would seem to show that a supply of the accessory substances is absolutely essential in a proper diet. Although they are present in varying amount in a large variety of the common foodstuffs, they may be best obtained by including in the daily dietary an ample supply of green vegetables and particularly the inclusion of a certain amount of milk and fresh fruit.

Finally, the diet to be a sound one must contain a due proportion of indigestible matter to give bulk in the intestine and so to stimulate intestinal movement. Such indigestible material is readily obtained from the consumption of wholesome bread and vegetables rich in cellulose.

**Quantity**

The amount of the food ration may be estimated in the following three ways:

(a) By the amount actually serving as nutrition, by computing the quantities of nitrogen and of carbon contained in all the food consumed and by assembling all the excreta (urine, faecal matter, products of perspiration). There can thus be easily estimated the quantity of nitrogen and of carbons retained by the system during the experiment.

(b) By the statistical methods, by estimating for a large number of individuals living under the same conditions the food ration freely chosen (family food budgets). In this case it is necessary to remember that the majority of food taken is without effective nutritional effect and that in a mixed ration there is a loss of 8-10 per cent. when calculating the total calorific value.

(c) By the method based on a study of the gaseous respiratory exchanges.

---

### Table: Foodstuff Caloric Value

<table>
<thead>
<tr>
<th>Foodstuff</th>
<th>Italy</th>
<th>France</th>
<th>Germany</th>
<th>Great Britain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td>63.70</td>
<td>55.24</td>
<td>40.76</td>
<td>37.70</td>
</tr>
<tr>
<td>Vegetables</td>
<td>5.53</td>
<td>4.37</td>
<td>4.77</td>
<td>1.54</td>
</tr>
<tr>
<td>Fruits</td>
<td>0.88</td>
<td>1.00</td>
<td>2.50</td>
<td>2.70</td>
</tr>
<tr>
<td>Vegetable oils</td>
<td>2.13</td>
<td>3.85</td>
<td>2.13</td>
<td>14.28</td>
</tr>
<tr>
<td>Sugar</td>
<td>3.19</td>
<td>3.48</td>
<td>2.22</td>
<td>14.28</td>
</tr>
<tr>
<td>Meat, fish, game</td>
<td>4.86</td>
<td>11.88</td>
<td>15.70</td>
<td>15.96</td>
</tr>
<tr>
<td>Milk</td>
<td>1.51</td>
<td>4.31</td>
<td>8.62</td>
<td>7.07</td>
</tr>
<tr>
<td>Cheese</td>
<td>0.15</td>
<td>1.91</td>
<td>1.07</td>
<td>1.24</td>
</tr>
<tr>
<td>Butter</td>
<td>0.42</td>
<td>1.60</td>
<td>4.68</td>
<td>3.42</td>
</tr>
<tr>
<td>Fat (bacon)</td>
<td>2.67</td>
<td>—</td>
<td>1.69</td>
<td>7.27</td>
</tr>
<tr>
<td>Eggs</td>
<td>0.96</td>
<td>0.63</td>
<td>0.91</td>
<td>0.77</td>
</tr>
</tbody>
</table>

---

5 This figure has not been included in calculating the averages since it is obviously unduly high.

Taking the average number of calories obtained from the data under review, there is found for the different countries:

<table>
<thead>
<tr>
<th>Country</th>
<th>Protein substances</th>
<th>Fatty substances</th>
<th>Carbohydrates</th>
<th>Calories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>81</td>
<td>29</td>
<td>465</td>
<td>2,553</td>
</tr>
<tr>
<td>Italy</td>
<td>88</td>
<td>58</td>
<td>466</td>
<td>2,612</td>
</tr>
<tr>
<td>Russia</td>
<td>73</td>
<td>43</td>
<td>473</td>
<td>2,668</td>
</tr>
<tr>
<td>Germany</td>
<td>87</td>
<td>60</td>
<td>498</td>
<td>2,770</td>
</tr>
<tr>
<td>Austria</td>
<td>81</td>
<td>57</td>
<td>478</td>
<td>2,895</td>
</tr>
<tr>
<td>France</td>
<td>88</td>
<td>67</td>
<td>485</td>
<td>2,923</td>
</tr>
<tr>
<td>Great Britain</td>
<td>90</td>
<td>105</td>
<td>493</td>
<td>2,997</td>
</tr>
<tr>
<td>United States</td>
<td>89</td>
<td>(1274)</td>
<td>430</td>
<td>(3,308)</td>
</tr>
<tr>
<td>Central America</td>
<td>85.3</td>
<td>58.6</td>
<td>456</td>
<td>2,763</td>
</tr>
</tbody>
</table>

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The above table proves that each people has a special diet, and that each of them derives the principal elements of its diet from the vegetable or animal kingdom with the view to building up freely and according to instinct the food of the organism and the production of energy requisite for work.

Although protein is a necessary constituent of the diet, the general consensus of modern physiological opinion favours the view that the source of energy for the performance of muscular work is carbohydrate. The carbohydrate is supplied in the food in the form either of starch or sugar and, so far as is known, there are no physiological differences of quality in the ordinary carbohydrates. Since carbohydrates are the cheapest, most convenient and least perishable of foodstuffs, there is little need to stress their importance in the diet of workers.

It is difficult to estimate the daily quantity of carbohydrates necessary for the organism since fat may replace this category of foodstuffs; it is, however, known that the quantity of carbohydrates consumed by the average individual varies between 350 and 500 grm. per day.

---

2 This figure has not been included in calculating the averages since it is obviously unduly high.

Taking the average number of calories obtained from the data under review, there is found for the different countries:
which only reveals the quantities of energy expended. In estimating the respiratory quotient (proportion of the volume of carbon dioxide exhaled to the volume of oxygen absorbed), it is possible in an indirect manner to ascertain approximately the energy expended by the organism.

In the discussion of the quantitative aspect of dietetics, instead of speaking in terms of separate food principles the calorie value of diet is utilised. The values adopted are those of Rubner, viz. calorie value per gramme: protein 4.1, carbohydrate 4.1, and fat 9.3.

In this connection it is necessary to refer to the theory of the isodynamics of diet. According to this theory, a gramme of fat corresponds to 8.9 calories, which are likewise derived from 2.25 grm. of cane sugar; but according to Chauveau, however, 1.52 grm. of the latter can replace 1 grm. of fat. Once the minimum need for protein has been satisfied, for instance, the substitution of fats for carbohydrates or protein substances can take place. It is therefore possible to supply the need for energy of the organism by replacing 100 grm. of proteins or carbohydrates by 45 grm. of fat or vice versa, for these different quantities furnish the same amount of heat. Without going into too much detail, it is necessary to enquire to what extent isodynamic diets can be substituted one for another without inconvenience. It is obvious that there must exist some limits to the principle of isodynamics. Thus, for example, an undue increase of the protein rations would disturb the nitrogen balance; the carbohydrates and the fats, on the other hand, may almost totally replace each other.

An adult man whose body functions normally loses daily: 2,500 grm. of water (1,300-1,400 by the urine, 600 by perspiration, 400-500 by the lungs, and 100 by faecal discharge); 25 grm. of mineral salts (by the urine, faecal matter, perspiration); 280 grm. of carbon (by the urine, faecal matter, air: carbon dioxide); 18 grm. of nitrogen (by urea, uric acid, etc.); as well as energy calculated at about 2,600 calories.

The quantity of food required by man depends upon the sum of the demands made upon him for the expenditure of energy, the most variable of these demands being that for the performance of muscular work. It is obvious that at complete rest there is a steady utilisation of energy (maintenance of body temperature, respiratory and cardiac activity). This is known as the "basal or standard metabolism" and it has been found to bear a relation to the surface area of the body, although in actual fact the mass of active tissue (muscle) is probably the important factor. Under definite conditions it is determined that the adult man between twenty and fifty years of age has a metabolism of approximately 40 calss. per hour per sq. metre, i.e. of approximately 960 calss. per diem. As the average adult (in Great Britain) has a surface area of some 1.7 sq. metres, this would give a daily metabolism of 1,652 calss. If it be assumed that the basal needs are 1,600 calss., there must be superimposed on this the expenditure during work and the increased expenditure of the subject during his leisure hours.

The addition to be made on account of the day's work necessarily varies much with the man's occupation. Obviously in sedentary occupations like tailoring, clerking, etc., the actual expenditure during working hours is very low, whereas in really strenuous occupations the cost may be four or more times higher than the basal. There has been much investigation into the amount of work which is performed by the "average worker" by the direct assessment by means of various ergometers of the actual amount of work performed, or, indirectly either by the determination of the increased metabolism or by a study of the amount of food consumed by subjects engaged in manual work.

It is generally stated that the average output of work by the average man in the course of the day lies between 10,000 and 12,000 kilogrammetres 2 per hour say approximately 90,000 kilogrammetres or 200 calss. per diem. 3

Of course this value, as has repeatedly

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1 The calorie employed in dietetics is the so-called large or kilogram calorie, viz. the amount of heat required to raise 1 kg. of water through 1°C. (from 17°C to 18°C).

2 Amount of external work is calculated in terms of kilogrammetres, i.e. the amount of energy required to raise 1 kilogram through 1 metre vertical distance. By direct experiment it has been shown that 426.8 kilogrammetres are equal to 1 large calorie.

3 Among the more recent investigators, Amar, who determined the daily work of 37 Algerians accustomed to hard manual work, found an output of 61,000 kilogrammetres per day. Experiments at the Rand mines (South Africa) showed an output of between 80,000 and 90,000 kilogrammetres per diem.
been shown, can be far exceeded for short bursts of work and even over longer periods when the subject is highly trained.

Although it may be assumed that the average daily output of external work is about the equivalent of 200 cals., this does not mean that the total extra energy expended by the body during work can be met by the ingestion of food which would yield 200 cals. of energy. It has been shown that the mechanical efficiency of the human subject is about 25 per cent., i.e. only one-quarter of the energy ingested in the form of food can be utilised for the performance of useful external work; therefore it follows that the food necessary to cover the work expenditure must be the equivalent of 800 cals.

### Food Values of Cheap Dishes for Workers

<table>
<thead>
<tr>
<th>Dishes</th>
<th>Protein per man in grm.</th>
<th>Fat per man in grm.</th>
<th>Carbohydrate per man in grm.</th>
<th>Calories per man</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Meat and Vegetables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roast mutton, potatoes</td>
<td>7.6</td>
<td>48.1</td>
<td>88.0</td>
<td>1,101.7</td>
</tr>
<tr>
<td>Cold beef, beetroot, potatoes</td>
<td>6.4</td>
<td>59.9</td>
<td>91.8</td>
<td>1,160.1</td>
</tr>
<tr>
<td>Roast beef, potatoes</td>
<td>5.5</td>
<td>47.1</td>
<td>96.8</td>
<td>1,061.2</td>
</tr>
<tr>
<td>Steak pudding, potatoes</td>
<td>4.7</td>
<td>42.8</td>
<td>111.5</td>
<td>1,046.7</td>
</tr>
<tr>
<td>Liver, onions and potatoes</td>
<td>4.5</td>
<td>6.3</td>
<td>109.9</td>
<td>672.6</td>
</tr>
<tr>
<td>Sausages, potatoes</td>
<td>4.1</td>
<td>41.0</td>
<td>107.0</td>
<td>996.5</td>
</tr>
<tr>
<td>Meat and potato hash</td>
<td>4.8</td>
<td>42.9</td>
<td>166.0</td>
<td>1,277.6</td>
</tr>
<tr>
<td>Bacon, peas, potatoes</td>
<td>4.0</td>
<td>29.4</td>
<td>137.6</td>
<td>898.8</td>
</tr>
<tr>
<td>Steamed beef, turnips, potatoes</td>
<td>4.2</td>
<td>5.9</td>
<td>112.2</td>
<td>855.1</td>
</tr>
<tr>
<td>Meat and potato pie</td>
<td>4.3</td>
<td>42.9</td>
<td>136.3</td>
<td>1,016.5</td>
</tr>
<tr>
<td>Shepherd's pie, potatoes</td>
<td>4.2</td>
<td>24.3</td>
<td>136.7</td>
<td>898.8</td>
</tr>
<tr>
<td>Yorkshire pudding, potatoes</td>
<td>2.2</td>
<td>5.8</td>
<td>124.6</td>
<td>651.3</td>
</tr>
<tr>
<td>Pea soup, dumplings, potatoes</td>
<td>1.9</td>
<td>41.4</td>
<td>100.9</td>
<td>877.5</td>
</tr>
<tr>
<td>Bread, potatoes</td>
<td>1.8</td>
<td>1.2</td>
<td>131.9</td>
<td>849.0</td>
</tr>
<tr>
<td>Beans, parsley sauce, potatoes</td>
<td>1.7</td>
<td>7.9</td>
<td>161.0</td>
<td>889.4</td>
</tr>
<tr>
<td><strong>Puddings</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boiled plum pudding</td>
<td>6.6</td>
<td>10.2</td>
<td>81.0</td>
<td>454.0</td>
</tr>
<tr>
<td>Boiled raisin pudding</td>
<td>7.3</td>
<td>10.6</td>
<td>67.8</td>
<td>406.5</td>
</tr>
<tr>
<td>Boiled cabinet pudding</td>
<td>13.9</td>
<td>9.1</td>
<td>100.6</td>
<td>667.1</td>
</tr>
<tr>
<td>Tapioca pudding (mean of 3 days)</td>
<td>7.2</td>
<td>9.7</td>
<td>60.3</td>
<td>364.3</td>
</tr>
<tr>
<td>Rice pudding (mean of 2 days)</td>
<td>9.6</td>
<td>9.5</td>
<td>56.8</td>
<td>360.6</td>
</tr>
<tr>
<td>Jam tart</td>
<td>5.3</td>
<td>10.8</td>
<td>70.6</td>
<td>411.6</td>
</tr>
<tr>
<td>Baked jam pudding</td>
<td>8.7</td>
<td>10.0</td>
<td>77.9</td>
<td>485.3</td>
</tr>
<tr>
<td>Boiled marmalade pudding</td>
<td>9.5</td>
<td>13.8</td>
<td>87.7</td>
<td>506.9</td>
</tr>
</tbody>
</table>

As regards the expenditure of energy over the basic level during the free time at the worker's disposal, this naturally varies with the temperament of the worker, the opportunities for taking exercise, the weather, etc. As a result of many observations (in Great Britain), it may be stated that an increase of 75 per cent. over the basal requirements will amply cover the average expenditure during this period.

Finally, the worker must sleep. It has been shown that during sleep the level of metabolism is at least 10 per cent. below the so-called basal level.

If the above assumptions and experimental data be accepted the total daily output of the average man (1.7 sq. metres surface area) engaged in fairly strenuous work may be stated as follows:

**Working Day Expenditure**

- 8 hours' sleep at 62 cals. per hour = 496
- 8 hours' work at 68 cals. (basal) per hour, plus 20 cals. work increment x 4 (assuming 25 per cent. mechanical efficiency) = 1,344
- 8 hours' free time at 68 cals. (basal), plus 75 per cent. increase = 302
- Total cals. = 2,792

This is the cost per working day. But all days of the week are not working days, so the above data must be retabulated on a weekly basis and then divided by 7 to get the average daily expenditure per week. If we assume a forty-eight hour working week, then the data are as follows:

**Weekly Expenditure**

- 56 hours' sleep, 62 cals. x 56 = 3,472
- 48 hours' work, 168 cals. x 48 = 8,960
- 64 hours' free time, 119 cals. x 64 = 7,016
- Total cals. for week = 19,152
- Total cals. per day = 19,152 / 7 = 2,736

Thus the daily expenditure may be assumed to be approximately 2,700 cals. In order to meet this expenditure, it does not suffice in practice to give the exact equivalent of the output in the form of food as purchased, for this is not identical with food absorbed. The loss in the form of waste and refuse in cooking and digestion must always be taken into account. This loss of course varies with the nature of the food taken; it is negligible for example with
bread, but it may be very considerable with meat and vegetables. As a general rule, the food as purchased should have a utilisable calorie value about 10 per cent. higher than the absolute net demands. Thus to translate the calculation given above into terms of food demands, the value should be raised from 2,736 to 3,000. It can be said then that the average man engaged in hard manual labour should receive approximately 3,000 cals. per diem. This figure is in fair agreement with many of the values which have been previously determined both by this and other methods of calculation. Rubner, one of the most experienced of all Continental workers, put the needs of the average worker on his working days at 3,100 cals.

According to this expert, a man weighing 70 kg. expends (in net cals.) daily:

<table>
<thead>
<tr>
<th>Calories expended</th>
<th>in 24 hours body weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>At rest relatively speaking</td>
<td>2,303 32.9</td>
</tr>
<tr>
<td>At very light work</td>
<td>2,445 34.9</td>
</tr>
<tr>
<td>At average work</td>
<td>2,888 41.0</td>
</tr>
<tr>
<td>At hard labour</td>
<td>3,362 48.0</td>
</tr>
</tbody>
</table>

Atwater, the American investigator, put the needs somewhat higher — 3,700 to 3,800.

This author, along with Gautier and others, fixes as follows the average ration per day of workers engaged on hard work: carbohydrates 630 grm., fat 85 grm., proteins 152 grm.: calories (figure arrived at by computation) 3,884. The production of work would therefore appear to necessitate a surplus of about 1,700 calories. This is probably due to the fact that the mode of life and the physique of the American worker differs from that of the European worker, but, at the same time, it must be doubted if his assessment was a perfectly legitimate one. Obviously those engaged in the lighter forms of work, and they perhaps form the bulk of the working population, require a relatively smaller intake, and conversely those engaged in really strenuous work require more.

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Prof. E. P. Cathcart (Glasgow).

Foot and Mouth Disease

Foot and mouth disease is an affection which can be transmitted to human beings, but is more particularly a disease of cattle and swine, sometimes, however, attacking sheep, horses, the camel, dromedary, giraffe, antelope, chamois, deer, etc., and perhaps even hens.

Clinically it is characterised by fever and especially by a vesicular eruption of the skin and mucous membrane, particularly on the mouth and tongue. The vesicles open in the early stage of the disease, leaving superficial ulceration with a bright red base which rapidly heals.

The virus, as proved by the well-known experiments of Loeffler and Frosch (1898), is a filter-passing virus. According to very recent research carried out by means of X-ray photography, the virus consists of minute bacilli, about 0.1 micromillimetre in length, often joined in couples (Frosch) and which have been successfully cultivated by several experts, Frosch designated these small bacilli Loeffleria nevemmanni.
The virus is chiefly located in the lymph of the vesicles which is fairly active, since 1/5000 cc. suffices to bring on the disease in cattle. The virus is also found in the blood in course of the fever and sometimes (according to Terni) in the following organs: myocardium, liver, kidneys. The organic products (saliva, milk) become virulent if contaminated by the lymph of the vesicles when these open. This virus, which can be preserved for a long time—three to four months in a refrigerator—offers on the other hand but feeble resistance against natural and artificial agents of destruction. It can be killed in ten to thirty minutes by a temperature of 60-70°C.; by formol (at 2 per cent.) in one hour; by soda (at 3 per cent.) and by hydrochloric acid (1 per cent.).

Experiment has shown that it can be transmitted to the guinea-pig (Waldmann and Pape). Animals which have recovered possess a certain degree of immunity which, however, does not last long and varies in degree.

Transmission of foot and mouth disease to man is neither certain after exposure to infection nor very frequent; the possibility of transmission has been proved some time ago, not only by epidemiological enquiry and clinical study, but also by direct experimental tests. The liquid from the vesicles in human beings suspected of originating in contraction of the animal malady was transmitted to cattle by inoculation (Bertarelli) or to guinea-pigs (Gerlach).

**Dangers**

Infection is most likely to be contracted by workers engaged in tending sick animals, in milking cows, making cheese and coming into contact with milk contaminated by the virus, as well as by butchers, slaughter-house workers, and veterinary surgeons. An old case quoted by MacBride (1869) was that of a butcher who caught the disease by placing an infected knife between his teeth. From the rarity of cases amongst human beings it may be concluded that specially favourable conditions, such as wounds in the skin and mucous membrane, or a particularly active virus, must be present to induce cases of so-called malignant foot and mouth disease.

**Statistics**

The first case of foot and mouth disease amongst human beings was reported by Segar in 1765.

In 1902, J. Bowen, of Boston, reported a case of eruption resembling pemphigus with fever and grave general symptoms. He drew attention to the fact that an outbreak of foot and mouth disease existed at the time, and pointed to a possible connection between the two.

Pernet has collected particulars of 16 cases, the half of which affected butchers; amongst the remainder of cases, contact with infected animals or contaminated animal products was established. Allen has reported a case affecting a blacksmith.

**Symptoms**

When human beings are affected an incubation period of three to eight days is generally followed by fever, headache, pains in the sacral region, discomfort and inflammation of the bucal mucous membrane, on which vesicles rather larger than those characteristic of herpes appear, being at first transparent, then thick, located chiefly on the tongue, cheeks, towards the front of the mouth, on the lips, around the nose and on the conjunctivae. These vesicles open early, leaving painful ulceration, accompanied by abundant and troublesome salivation. Vesicles may be located also on the fingers (especially of dairy workers), on the toes and sometimes over the whole body. The disease is further accompanied by intestinal disorders giving rise to anorexia, diarrhoea and constipation, sometimes nasal, venal, and intestinal haemorrhage, and more rarely orchitis. The disease usually runs its course in two weeks. It is not fatal apart from exceptional instances in the case of infants.

Diagnosis of the disease in man is difficult, for the occurrence of aphthous stomatitis in localities where foot and mouth disease is present amongst cattle or swine is not sufficient evidence that the affection is really foot and mouth disease. It must be remembered that milk from infected sources has often been consumed without giving rise to cases of the disease amongst human beings. As very sure means of diagnosis are not yet available, it is necessary to resort to animal experiment (guinea-pigs or cattle) for the proof of the existence of foot and mouth disease amongst human beings, taking account, however, of the fact that cattle are sometimes immune from this infection.

**Prophylaxis**

This belongs to the domain of the veterinary surgeon and includes: isolation of the animal, sometimes killing the cattle infected, disinfection of the...
bedding and tools and of the byres, destruction of forage which may have been contaminated by saliva, instruction of the workers tending the cattle in measures of personal hygiene, prohibition of consumption of milk from infected byres, inspection of markets, cattle fairs and slaughter-houses, etc., to prevent products from infected animals (skins, heads, tongues and hoofs) from being put on the market prior to disinfection. It is equally necessary to direct attention to means of transport, and to ensure the supervision of the health authorities over trading in milk and cheese, and the sterilising of milk destined for consumption.

Recent research in Italy gives reason to believe that a practical method of effective vaccination may shortly be discovered.

Foot and mouth disease is not placed on any list of occupational diseases liable to compensation.

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Forges and Ironworks


Under the heading of "forging" are included operations identical in nature, but different in importance, according as they are concerned with the construction of immense objects or the fashioning of small articles.

In the iron trade, forge work and iron and steel rolling are carried out in works where puddled iron or steel is received direct as raw material in blocks or in bars, and Bessemer or Martin steel in ingots, blooms or billets; here they are brought to marketable shapes by forging with shingling hammers, and by pressing or rolling. "Reheating" old iron or steel consists in bringing them to melting point in Martin-Siemens furnaces. Other operations which should be mentioned are the following: putting up into lots or making up into bundles, reheating in furnaces, welding by hammering, and rolling out into merchant bars and plates.

The technique consists in placing pieces of iron and steel, other than moulded pieces or pieces worked up by the blacksmith, with bars of metal of a suitable thickness, and forging them together either by machine hammer or steam hammer, or by forging presses which may be mechanical, hydraulic or steam. Feeding into furnaces for reheating is done by fixed or gantry cranes. The process of stamping out iron or steel while hot makes it possible to fashion complete pieces quickly. The anvil and hammer of the drop hammers or the upper and lower surfaces of the presses are supplied with matrices or stamps of tempered steel in which the impress is hollowed out so as to give to the pieces the desired shape. Stamping produces concave pieces. Punches, actuated by hydraulic or steam presses, are used to force red hot metal into moulds or matrices of suitable shape. In order to obtain the desired shape, the operation must be effected successively in different moulds (domes, cupolas, shells, and cylinders for liquified or compressed gases).

The products of a medium iron forge may include such articles as instruments and iron and steel tools used in various industries by locksmiths and wheelwrights. They stand between heavy articles made in large iron-works and the manufacture of ironmongery or of small hardware. This work includes in some of its technique the general processes already mentioned of rolling, forging with hammer or press, stamping, and punching.

Among the work carried out at small forges are some operations in the manufacture of edge tools, ironmongery, and, especially, the work of the shoeing smith, who forges red-hot iron by means of a hand hammer on an anvil. His assistant, standing in front, strikes the iron with a hammer alternately with the blacksmith, who with pincers holds the piece to be forged on the anvil. It should be noted that to-day shoes for horses and oxen, which were formerly made by these smiths, are turned out by machinery: pieces of iron, heated to whiteness, are roughly shaped in rolling mills, and curved by machine; then the rough-cast article is stamped with an eccentric machine which pierces the nail holes at the same time. Agriculturist, wheelwright work, for the repair of farm carts, ploughs and farming appliances, as well as locksmiths' work, is often associated with horse-shoeing, especially in villages.

Sources of Dangers

The sources of danger and the degrees of the risk vary according to the conditions under which these operations are carried out. For instance, in operations involving large pieces of work powerful machines come to the aid of the worker. But, while it is true that these machines make work easier and less strenuous, they introduce, on the other hand, a new source of danger which is not found in the small forge during the manufacture of small articles. However, the chief causes of trouble are, on the whole, similar; and these can be classified as follows:

Exposure to high temperatures and radiant heat given off by the pieces under construction, or from the heat-
ing furnaces. Exposure to sudden changes of temperature. These risks are more serious in big forges than in small.

Exposure to intense luminous radiations when working in front of furnaces on articles which have been brought to a red-white heat.

Exposure to fumes and gases from the furnace-fires; to dust from coal and metals; to incandescent sparks which are thrown off during forging; to various fumes from pickling or tempering in lead; to cyanide of potassium; to vapour of acrolein arising from oil.

An important source of trouble arises from the attitude and occupational movements assumed which call for strenuous physical effort or lead to tiring positions, causing fatigue, either localised to definite groups of muscles or affecting the whole body.

In most ordinary forges, when there is no machine hammer, the piece of iron is placed on an anvil and hammered by a number of strikers who raise a heavy weight and let it fall forcibly, and then repeat the process for several minutes. This action calls for strenuous muscular effort. In other circumstances fatigue of the arm results from exaggerated distension of the shoulder joint, following upon the twisting movement from forward backwards which the arm executes when swinging the hammer. The attitude adopted by blacksmiths standing with the left leg advanced, throws the whole weight of the body on to the right leg, and causes a torsion of the trunk at the level of the lumbar region, to say nothing of the fatigue and varied troubles to which this attitude may conduces.

Note should also be made of exposure to noise and vibration, and to concussion caused by the blows of the hammer, transmitted from the end of the bar which is being forged to the arm of the blacksmith; the effects are most tiring and painful.

Statistics

The result of all these causes of trouble which have been mentioned is that the health of forge-workers is far from satisfactory.

Wenzel gives the following figures drawn from the statistics of the Sickness Office of Leipzig and relating to the yearly average per 100 workers of cases of disease and death:

According to some old statistics of Sommerfeld, tuberculosis used to be very common among forge workers. But this disease is rare, according to Kober and Hayhurst, in the United States. American statistics for 1909 give the following rates of mortality per age group:

<table>
<thead>
<tr>
<th>Age-group</th>
<th>Per 100 deaths from all causes of the age group shown</th>
</tr>
</thead>
<tbody>
<tr>
<td>All causes</td>
<td>Pulmonary tuberculosis</td>
</tr>
<tr>
<td>25-34</td>
<td>226</td>
</tr>
<tr>
<td>35-44</td>
<td>280</td>
</tr>
<tr>
<td>45-54</td>
<td>400</td>
</tr>
<tr>
<td>55-64</td>
<td>485</td>
</tr>
</tbody>
</table>

Diseases of the heart form one of the most frequent causes of sickness. They form, according to Shann, 10.44 per cent. of all diseases reported.

As regards Great Britain the mortality for this occupational group appears for 1921-1923 with figures which are below the average and have no particular interest.

An enquiry carried out in Russia in 1926 on 156 forge workers showed in 61 cases, or 38.4 per cent., hypertrophy of the left side of the heart. The frequency of
this condition increases with the length of service. Among workmen with over thirty years' service it was found in 73.7 per cent. of cases; but among those with less than five years in only 14.9 per cent. of cases. Further, this hypertrophy is only met with in persons over twenty-five years of age; 26.8 per cent. of the cases were in the age group 25-34, and 83.5 in the age group 55. Out of the 61 cases of hypertrophy, 22, or 36 per cent., showed myocarditis. Early sclerosis of the peripheral arteries has also been noticed. Workers with less than five years' service exhibited rigidity of the vessels in 40.7 per cent. of cases; while it was present in 100 per cent. of those with more than thirty years' service.

It is remarkable that the sickness figures are unfavourable, all the more so seeing that according to Maisonneuve, ironworkers are generally strong men, of sound constitution, not only because the nature of their work develops their constitution early, but also because the fatiguing nature of the work works out a considerable number at the start (Israel).

PATHOLOGY

Among the general disorders should be mentioned that, in the absence of true heat stroke, the effect of high temperatures may make itself felt on the whole body by violent headaches due to inflammation of the frontal sinuses, by attacks of malaise and depression, by acceleration of both pulse and respiration, and by a rise of temperature. Duvernoy, for example, has observed in an iron worker, before work: pulse rate 75, respiration 16 and temperature 37° C.; after work: pulse 129, respiration 30 and temperature 37.6° C. Even though the heat may not give rise to pathological conditions, it causes at the least profuse sweating and thirst which may mark the onset, or be the cause, of morbid conditions.

Various cutaneous lesions due to the effect of dust, abundant sweat, and heat are seen in the form of erythema, pustules, boils, and abscesses on the arms, armpits or umbilicus, eczema and especially of sweat rashes which occur principally on the hands, forearms, and on those parts of the body which are most exposed to the effect of the furnaces or incandescent material. The development of these eruptions is, however, favoured by insufficient personal cleanliness.

Burns occur on various parts of the body, notably on the back of the hand. Vernois regards the numerous white scars which these small burns leave as one of the distinctive characteristics on the hand of a working ironworker.

Among the stigmata of this occupation may also be mentioned callosities on the surface of the fourth and fifth fingers caused by handling the hammer (Schlossmann), and hygroma of the elbow (Prosser White).

Coryza is the most common of the lesions of the nasal mucous membrane. Masson reports that under the influence of heat and occupational activity this coryza can be of an intensely acute type. On the other hand, diseases of the eyes occupy a much more important place. First of all comes blepharitis, due to the effects of radiant heat and to the deposit on the edges of the lids of small particles of coal or metal. Cicatrices and small ciliary-glandular cysts are also seen from the effect of sparks, flying up from the blows of the hammer, which sometimes also cause serious conjunctivitis and burns on the cornea. It is not unusual for bits of metal to become embedded in the cornea and leave there a blackish stain of iron oxide.

Among the functional lesions are contraction of the pupil followed by dilatation (Layet); but this lesion observed by Novak has not been confirmed by Walther. Weakening of the sight, presbyopia with diminution in the power of accommodation, various changes in the media of the eye, such as opacities of the lens and cataract, are directly attributed by some experts to the effect of radiant heat. Very few eye troubles are found among ironworkers due entirely to the effect of luminous rays.

The ear is frequently injured, chiefly by dust, which, combined with accumulated wax, leads sometimes to the obliteration of the external auditory meatus and somewhat frequently to furunculosis.

Further, noises cause lesions of the internal ear. Out of 75 ironworkers examined by Gottstein and Kaiser, only 29 had good hearing, 16 heard badly, and 30 very badly. (For further details, see articles "Noises" and "Diseases of the Ear").

Various respiratory affections, such as angina, bronchial catarrh, and emphysema of the lung, are common and are caused chiefly by sudden changes of temperature. It should be noted that serious pulmonary affections are comparatively rare and phthisis still more so, which, according to some authorities (Kober and Hayhurst), seems to be due to the fact that workmen of delicate constitution quickly leave this occupation. However, when phthisis does appear, it develops rapidly; and according to Marten it forms
the commonest cause of mortality, accounting for 33 per cent. of deaths.

The shocks caused by the blows of the hammer are fatiguing and painful to the thorax; while those caused by the fall of the large steam hammers, to be found in the large works, often cause spitting of blood and pains in the right hypochondrium (see irritant fort.) According to Masson, the vibration which results from successive blows of pile hammers may cause pulmonary and hepatic congestions.

Digestive disorders consist essentially of gastric distress and diarrhoea, caused by taking the drinks or alcohol. Turner, Thackrah and Shann, each in his day, described intemperance among English ironworkers.

Circulatory diseases consist chiefly of hypertrophy of the heart, lesions of the aortic valves and sclerosis of the arteries, due especially to a rheumatic diathesis and to great and repeated activity of the upper limbs. An increase of systolic and diastolic pressure is found quite often.

Arthritis of the shoulder and elbow, as well as crepitating teno-synovitis of the wrist, have also been reported (Schlossmann). Varicose veins of the lower limbs, ulcers, and congested sores, the development of which is favoured by the adjuvant action of heat, are also due to prolonged standing. Among workmen the harmful position assumed during work lead to deviations of the vertebral column, with genu valgum, and sometimes to flat feet.

There still remains to be noted the comparatively high number of hernias met with among ironworkers, due to the combined effect of occupational postures and strain efforts.

There must also be borne in mind the various poisonings which may occur, due for instance to carbon monoxide or lead, in addition to accidents. Among the latter, burns of greater or less severity must occupy the first place; next come haemorrhages from tools or the articles manipulated, and various wounds from excoriations and punctures.

Hygiene

Big forges in which are encountered serious disadvantages from fumes, noises and earth tremors, belong to that category of works grouped together and subjected to certain special regulations; these stipulate for the use, as far as possible, of iron frameworks, and for the closing of all openings on to the public roads or on to neighbouring properties. Forges, blast furnaces and other noisy machines must not be placed against party-walls; drop hammers must be set up in the centre of the factory and every possible precaution must be taken to deaden the fall and lessen the noise and shaking. The
anvil-block of the steam hammer should be placed on piles or foundations around which are placed sand, sawdust or other insulating material for preventing the spread of tremors.

Measures of a more general kind should also be adopted; thus the workshops which should be spacious must be well ventilated; the air inlets and windows must be placed at the upper part of the buildings, so that the workmen are below the draughts.

Exhaust cowls, placed above the furnaces should direct all fumes and gases into a sufficiently high chimney, provided with baffles at the upper part to prevent the scattering of sparks. In some cases coke should be used as fuel exclusively.

If necessary, there must be localised suction for dust which must be conducted into the central chimney of the works.

Natural and artificial lighting should be arranged so that each working place is adequately lighted (see article "Lighting"). Periodical cleaning of lamps which become obscured by dust and smoke is required.

Adequate means should be taken to regulate the temperature and to reduce the heat and dryness of the air, as well as to prevent the dissemination of dust by spraying. In order to avoid the personnel being exposed to sudden changes of temperature, warmed cloakrooms should be provided; and these, as well as the washing accommodation and conveniences, should be so situated that the workmen do not have to cross the yards to reach them.

The extensive use of such mechanical devices as cranes, hooks and winches should be adopted to help in reducing fatigue.

These general measures should be completed by measures of personal hygiene, such as wearing special working clothes, shoes, aprons, leather leggings, and protective goggles of metal gauze with coloured glass if necessary (see article "Personal Hygiene"). Workmen should be instructed to change their clothes, soaked in sweat, as soon as there is an interval in the work.

The need for personal cleanliness is considerable; frequent washing of the face, eyes and ears, and general care, should be recommended. For this reason requisite accommodation with lavatories and douche-baths should be provided for the personnel.

Instruction should be given to workmen as to the risks they run, especially as regards excess in drinking and the dangers from taking plain water dur-
tions with water and alcohol, but not with ether. In addition it contains traces of formic and acetic acid and methyl alcohol.

Production

Trillat's industrial process, perfected by Sabatier and Mailhe, uses the vapour of methyl alcohol obtained by causing the latter to boil in a copper vessel. The vapour given off passes along a copper tube bent at a right angle, reaching a copper tube of much larger diameter containing fragments of coke or spirals of copper brought to red heat. The alcohol vapours mix with the air in entering the tube containing the coke and become oxidised. The oxidation of 100 grm. of methyl alcohol at 30 per cent. requires 109 litres of air. The products are subjected to a further oxidation by rapid aspiration effected either by a simple jet of water or by more complicated mechanism. The formalin obtained is a crude solution in water containing 29 to 30 per cent. by weight of formaldehyde. 35 to 40 per cent. methyl alcohol, 30 to 35 per cent. water with traces of formic and acetic acid.

Formaldehyde can also be obtained by causing chlorine and bromine to react on methyl alcohol, by heating dimethylacetate of formaldehyde with sulphuric acid, and by electrolysis of dilute methyl alcohol, etc.

Uses

Besides its use as a disinfectant (for which its efficacy, combined with the ease with which it can be used, makes it preferable to sublimate and sulphur dioxide), formaldehyde is employed in quite a number of industries:

- Foodstuffs: in the preparation of the wort in the alcohol industry, especially when inferior raw materials are used or when there is bacterial contamination. In addition to its action in this respect, formaldehyde exerts an activating influence on yeast; it has been used as a preservative agent for milk (in some countries its use for this purpose is forbidden).

- The aniline colour industry: because of its great reacting capacity and the readiness with which it condenses. Combination of formaldehyde with aniline produces anhydro-formaldehyde aniline. Formalin and aniline yield diaminodiphenyl methane, which, by oxidation, gives paranilamine. The homologues of aniline behave in the same way with such effect that a great number of colours are prepared by this means.

- It is also used in the making of artificial amber. A mixture of acetic acid, ammonia, soda, sulphite of sodium and other substances are heated in a porcelain dish. The mixture becomes concentrated and, on being allowed to rest, yields a whitish-grey mass, of resinous consistency, to which is added as required the colouring matter; it is then run into long glass tubes, 3 cm. in diameter. As the precipitated matters are heated fumes of carbolic acid, ammonia and formaldehyde are given off, most of which are carried away by locally applied exhaust ventilation, but of which some may nevertheless escape into workrooms situated on lower floors.

- Making of artificial horn and ivory: formalin in a strength of 40 per cent. in combination with phenol or cresol is used for the preparation of bakelite, resinite, condensite, etc., substances serving for the manufacture of ornaments in imitation of amber (heads of umbrellas, sticks, etc.), as well as varnishes and lacquers. The action of formaldehyde on casein is also utilised to obtain a substance analogous to horn (galalite, omnilite, etc.).

- In the photographic industry it is applied for hardening gelatine in making plates and films, and in the leather industry for tanning and making leather. Besides its disinfecting action formalin seems to harden and render insoluble the skins used. Thus, e.g., the firm of Pullman in Great Britain has succeeded, in a time varying from half an hour to six hours, in tanning skins by using a dilute solution of formalin with soda added and thus obtaining a formalin-tanned skin analogous to a chrome-tanned skin.

- In the brush and broom industry it is utilised for disinfecting bristles and horsehair; in the textile industry for hardening gelatine in printing Indian materials; for dyeing stuffs either to strengthen the tissue, or as a mordant for the colours such as hydrosulphite derivatives; in the cotton industry 9 and 13 per cent. solutions are used ("Defiance" antisepctic; conditionite, antimaldek); in the woolen industry for the disinfection of wool infected with anthrax.

- In the chemical industry it is used in the manufacture of artificial silk (to strengthen the solidity of the silk and to enable it to be used in the manufacture of stuffs for clothes); in soap manufacture, paper factories, manufacture of inks, etc.; in the making of various organic substances,
many of which start from formalin as a basis: in the glass industry to dilute certain powders used in etching on glass; in the electro-technical industry, etc. Formaldehyde is given off in certain stages of rubber manufacture when its compounds are used as accelerators for vulcanisation (see article "Rubber"). It is present, too, in the products of incomplete combustion and is the cause of smarting sensations in the eyes and throat.

As a disinfectant formaldehyde is used in the form of vapour obtained generally by burning pastilles of trioxymethylene (in special apparatus) or in solution. The different kinds of apparatus for disinfection with formaldehyde can be thus classified:

(a) apparatus vapourising aqueous weak solutions of formaldehyde (apparatus of Trillat, Brochet, Fournier, etc.);
(b) apparatus diffusing formaldehyde as a product directly by oxidation of methyl alcohol (apparatus of Kuhn);
(c) apparatus using the polymeres of formaldehyde and notably trioxymethylene (apparatus of Scheering, etc.).

Toxicity

Foremost is the irritating action of formaldehyde on the skin and mucous membrane. It diminishes the secretion of sweat, makes the epidermis hard and resistant. By its coagulating action on albuminoids it damages the red blood cells as well as the conjunctival tissue. Its necrotic action on these tissues is well known and easily produces scarring. Prolonged use of solutions of from 2 to 10 per cent. set up exccematous lesions of the skin, vesicles, rhagades and ulcerations. Concentrated solutions (as of commercial formalin) exercise an effect on the degree of toxicity which explains the necrotic action on the tissues.

Observations made on man and animals (by Iwanoff in the Institute of Hygiene at Wurzburg under Prof. Lehmann) show that if the proportion does not exceed 0.25 mg. per litre during 3½ hours the action is so slight that after the lapse of some hours no effects remain. If the dose reaches 0.8 mg. per litre for 4 hours the effect does not pass off until after some days owing to the damage done to the respiratory passages. Doses of 0.8 mg. acting for 8 hours and of 2 mg. lasting for 4 hours irritate the lungs so much as to produce pulmonary haemorrhages, emphysema and pneumonic or supplicative lesions following on secondary bacterial infection. The pneumonia is so pronounced that generally the animals die of it.

A concentration of 6 mg. acting for 3 hours sets up a narcotic action in addition to the irritating action on the lungs and cornea. The animals die some hours after the experiments. Ten mg. per litre causes death in 3½ hours, and in one case haemolysis of the red blood cells and blood coloured serum was observed. Irritation of the lungs is to be regarded as the principal danger.

The powerful disinfecting property of formaldehyde shows itself even in concentrations of 0.1-0.2 per cent. on anthrax and diphtheria bacilli, and even in a dilution of 1: 50,000 bacterial growth is inhibited. The vapour as well as formalin solution are an excellent means for the destruction of anthrax spores (see article "Wool-disinfection"). This disinfecting action depends not only on the chemical combination of the formaldehyde with albuminoids, but also on its power of bringing lipoids into solution.

Symptoms

Acute intoxication by formaldehyde does not occur industrially except on accidental absorption of liquids containing the product. In addition to irritation of the conjunctiva, mucous membrane of the pharynx, oesophagus and stomach with nausea and vomiting, dyspnoea, and a state of torpor with vertigo have been observed. Occasionally there has been anuria (following on renal irritation).

The dangers and effects from use of substances containing formaldehyde have been known for a long time. It is certain that the increasing use of formaldehyde entails a large number of skin diseases. Individual susceptibility is noticeable; some persons become acclimatised, others are markedly sensitive. A prolonged use of 2-10 per cent. solutions sets up exccematous skin lesions especially on the fingers and hands which may be covered with vesicles, rhagades, ulceration which may eventually spread to other parts of the body. Among particularly susceptible individuals the use of powders containing formaldehyde as a remedy for excessive sweating in the feet and axillae may set up dermatitis and eczema. In numerous individuals urticaria breaks out which may cover the body. As a rule, however, eczema does not appear except after prolonged use of formaldehyde.

Erythema in the form of a rash has also been reported.

The lesions mentioned often affect
workmen engaged as disinfectors, chemists, medical men, dentists, laboratory assistants, gardeners (from use of formalin as a parasiticide) and may set up inflammations more or less severe, lymphangitis, etc. Recently (1929) the Medical Inspector of Factories in Great Britain reported cases of dermatitis among workmen employed in polishing celluloid substitutes containing formaldehyde (0.015 per cent. of the total weight). Chajes has also described dermatitis and eczema from relatively weak solutions (0.25 to 0.50 per cent.). Similar lesions have been described among workmen handling a paste to which a little formaldehyde had been added (not more than 1 per cent.) to preserve it. The workmen's skin had become very sensitive from continued contact with the paste so that very small quantities of formaldehyde sufficed to set up the particular lesion. The cases of dermatitis described by Sachs in the making of artificial amber involved mainly the face and hands.

**Nails. —** The changes in the nails are particularly characteristic. These, after long continued use of formaldehyde, become brown, soften and then decay, in the course of which the grooves become inflamed and give rise to suppuration of the matrix. In other cases the nails become scaly and friable, but in all the matrix becomes thickened and inflamed. Further, sometimes increased sensitiveness of the finger ends is felt with tightening pains extending occasionally up the arms.

**Mucous membranes. —** Besides the skin lesions irritation of the conjunctiva and mucous membrane of the respiratory tract is very frequent. Only exceptionally in literature have grave manifestations of intoxication by formaldehyde been mentioned. Brunnthaler has nevertheless published observations on himself. Prolonged use of formalin in his position as keeper of the Botanical Institute in Vienna induced acute catarrh of the nose and eyes, chronic pharyngitis and laryngitis, dyspnoea and acute nervous manifestations. Conjunctivitis and even bronchitis have been also described by Sachs among workmen manufacturing artificial amber.

The internal organs do not share in the damage done by formaldehyde. Troubles in the respiratory and gastrointestinal tract and nervous excitements, which, according to Brunnthaler, can become very marked and be accompanied by scintillating scotomas have been described but are very rare. These signs of chronic intoxication, however, are exceptional.

According to Chajes, quite a number of obscure occupational eczemas may possibly owe their origin to small quantities of formaldehyde. To this category belong the lesions met with in the brewing industry in which formaldehyde is used to clean casks and vats.

**Demonstration**

Traces of formaldehyde are present in the air of towns in which all manner of fuel and tobacco, etc., are burnt. Investigation should be directed to industrial fumes in the air of workrooms.

A strip of paper dyed with fuchsin, if placed in a stream of aspirated air which has been filtered through cotton wool first and bubbled through a series of bottles of water for a period of 120 hours at a rate of 180 litres an hour, becomes blue after some hours of contact.

The acid solution containing the formaldehyde is easily separated, and with neutral reaction may be distilled: on adding to the distillate morphine dissolved in concentrated sulphuric acid a bluish violet band appears (reaction of Marquis reversed).

For quantitative estimation of small quantities of formaldehyde in the air Lehmann recommends (according to Ronjin Iwanoff) aspiration of air through three tubes on which 10 bulbs are blown filled with water. The contents of the tubes are united; a solution of standard iodine is added and then, drop by drop, a solution of soda, until a slight brownish-yellow colour appears. At first this colour rapidly disappears, then a few drops of sulphuric acid are added and the yellow colour remains stable for about an hour. Sulphuric acid is then added until the sodium iodide is completely decomposed (addition of an excess is to be avoided). After standing for a quarter of an hour the acid solution is titrated with thiosulphate of soda. Each c.c. of the dec-normal iodine solution which has disappeared is equivalent to 1.5 mgr. of formaldehyde. The method depends on the oxidation of formaldehyde to formic acid by hypiodous acid.

**Hygiene**

Authorities agree that an atmosphere containing 1 part per 20,000 parts of formaldehyde renders respiration impossible. It should be remembered, however, that practically no such atmosphere can exist, because under the influence of several factors, even opposite in action one to the other (heat, cold, humidity, diminished pressure, etc.), the product undergoes polymeri-
sation into trioxymethylene. Inversely this again depolymerises itself even when cold partly to give rise to fresh vapour of formaldehyde.

Although there are no special measures of prevention to protect the workers against injury from formaldehyde, progress should always be in the direction of modifying the process so as to prevent contact with the skin. In the wool disinfection station at Liverpool use is made of box respirators, the filtering material being activated charcoal.

Legislation

Formaldehyde is included among the substances brought under the Workmen's Compensation Act in Switzerland and the State of New York and in Great Britain so far as skin lesions are concerned. In Switzerland one single case received compensation in 1918. So far as general and particular safety measures are concerned, the Association of the German Chemical Industry classes formaldehyde among the poisonous gases and harmful and explosive fumes.

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Dr. B. Chajes (Berlin).

Formic Acid


Formic acid (symbol H.CO.OH), which belongs to the series of fatty acids, is, in the pure state, a colourless mobile liquid having a penetrating smell. Its specific gravity is 1.22 and its boiling point is 101°C. Soluble in water in all its proportions, it also dissolves in alcohol and ether. It oxidises readily and consequently is a powerful reducing agent.

In industry formic acid is prepared by the Goldschmidt process by causing carbon monoxide to react on sodium hydrate at a high temperature and under pressure. The sodium formate thus obtained is displaced by sulphuric acid. The formic acid thus obtained is then distilled.

It is used to replace other organic acids: in the textile industry (for dyeing wool, silk and cotton and for mordanting); in the hides and skins industry (to get rid of the lime in delicate skins); as a substitute for lactic acid in the fermentation of alcohol; for the preparation of artificial dyes, soap, lacquers and varnishes (aeroplane industry), and as an antiseptic (breweries), etc.

Formic acid sets up, even in small doses, when injected subcutaneously into animals, very severe pain, hyperaemia and irritation. Among workmen it causes, especially, irritation of the mucous membrane (of the eyes, nose and throat) and dermatis (blisters, ulceration and even necrosis), which, however, only occurs in a serious form from use of the concentrated acid.

Numerous cases of irritation of the mucous membranes and dermatis were reported in Germany (1914), in Great Britain (1919), and in Switzerland (1919).

The vapour of formic acid being inflammable and giving rise on exposure to air to an explosive mixture, care should be taken, where it is made, to maintain good ventilation, to use electric light only, and strict measures should be taken to prevent fire.

The use of this material in solvent mixtures (lacquers, varnishes, etc.) should be prohibited. Strong formic acid is included in the Swiss list of substances for which compensation as in the case of accidents is granted.
Fulminate of Mercury


Chemical Properties

Fulminate of mercury (C₄N₃O₇Hg or C(NO₃)₂(CN)Hg), a very powerful detonator, is probably a salt of fulminic acid; it takes the form of fine silk crystals and is yellowish white in colour, soft, soluble in boiling water (only slightly so in cold) and in ammonia. If raised to a temperature of 180° C. when dry, or subjected to a blow or electric spark, the fulminate decomposes with detonation and evolution of red fumes (see later).

Preparation

The fulminate is obtained by reaction on alcohol of a solution of nitrate of mercury in nitric acid. Mercury is added to the nitric acid contained in a stoneware receptacle and is filtered through asbestos into glass balloons with flat bottoms. A green solution of acid nitrate of mercury results with evolution of nitrous dioxide fumes which, on contact with the oxygen of the air, turn red (nitrogen peroxide). The acid nitrate solution is then poured on to alcohol contained in large glass balloons in the proportion of 1 to alcohol at 80° C. or 11 of alcohol at 85° C. Other authorities state the proportion as 1 part of mercury to 8.4-11 parts of nitric acid and for 6.5 to 10.6 parts of alcohol at 90-96°.

The reaction evolves white fumes, and only a white precipitate of fulminate remains in the balloons below a colourless acid liquid. Sometimes this reaction is carried out at about 54° C., and occasionally a small quantity of cuprous chloride is added (to serve as a catalyst). Each balloon is connected by an air-tight earthenware pipe serving as a duct to carry the fumes away to a chimney stack. Each balloon also is placed in a basket provided with handles for transport to avoid risk of burns and inhalation of irritating fumes.

After the solution has cooled and is decanted, the fulminate is washed with as small a quantity of water as possible (the fulminate being soluble in it) and it is strained through silk gauze (for final washing). The two first operations are carried out in balloons placed under a penthouse with air circulating freely. The moist powder, sieved in filtered water through flannel and dried under a vacuum, is kept in a moist condition. It is only dried when it is to be used, and it is from this stage onwards that the handling of it is dangerous.

Drying is effected over a bain-marie, or more usually the powder is spread in a thin layer on wooden boards which are carried into a drying chamber of special construction heated by steam radiators. After an hour the powder comes out in the form of a white powder sensitive to the slightest blow. Each board carries 250 grm. of fulminate and the drying chamber is constructed to hold only four boards. The dry fulminate is sieved through sieves of horse-hair to obtain the fine powder necessary for the caps. The sieves have to be cleaned frequently to remove the particles which might give rise to an explosion.

The fulminate is used alone or mixed with other substances (nitrates, chlorates, sulphides of antimony, saltpetre, powdered glass, etc.). The operation of mixing requires the greatest precaution, because the fulminate detonates on receiving a shock or by friction. It is done either dry or when moist. To make the caps the mixture is placed in capsules and gently pressed.

Toxic Action

Fulminate of mercury has no particular specific toxic action, the various risks depending on the nature of the work done: the evolution of nitrous fumes and organic mercurial compounds in the course of manufacture; of dust in making the caps, etc., or contamination with the material; these constitute the principal dangers. The gases given off in detonation also require mention.

Nitrous fumes (see this article) are liberated when metallic mercury is dissolved in nitric acid; volatile organic compounds of mercury, of which the nature and action (on the nervous system) are not sufficiently clear, appear when the denatured alcohol is poured on the solutions. Besides these substances there must be recalled acetic ether, nitrite of ethyl, compounds of hydrocyanic acid such as cyanic acid, ethyl cyanide, perhaps organic mercurial compounds, the vapours of which might cause headache, vertigo, oppression, tremor and loss of consciousness (Pappenheim), and, in large doses, even death (Ram- bousek). Under certain conditions
Nitrate of ethyl can, according to Hamilton, cause cardiac weakness.

**Statistics**

Not many statistics as to the frequency of illness among fulminate workers are available, except in Great Britain, where the Medical Inspector of Factories reported 338 specific cases in the second half-year of 1916 and 232 cases in the first six months of 1917. An enquiry effected in Great Britain in 1920 by Dr. Bridge among 60 workers showed only five as being quite free from symptoms. Skin affections, principally on the face and on the hands (41), conjunctivitis (35), blepharitis (20), stomatitis (21), diarrhoea (30), nervous depression (25), menstrual derangement (20) were reported. Naturally several of these symptoms occurred in the same individuals.

Half of the fulminate workers in Bavaria examined by Koelsch presented slight lesions of the skin, mucous membrane, and teeth.

Even before the war inspectors (Belgian, French, British, etc.) reported cases of mercurial poisoning from munition factories. Between 1899 and 1913 in Great Britain 54 were notified (mercury poisoning due to fulminate characterised by tremor, gingivitis, digestive disturbance, etc.). Similar reports were made in every country during the war. On the other hand, a report emanating from the British Ministry of Munitions appeared during the war in which it was said that symptoms of mercurial poisoning were only rarely observed in view of the small quantity of mercury used.

Koelsch, after visiting a large number of factories in Bavaria, had not been able, as a result of his extensive enquiries, to find many workers suffering from mercurial poisoning either in the acute or chronic form. In some, however, who showed either subjective or objective symptoms he was able to detect small quantities of mercury in the urine (from 0.1 to 0.07 mg. in three out of eight workers examined).

**Symptoms**

Fulminate workers have been found to show symptoms (a) local (of the skin, mucous membranes, and teeth), and (b) constitutional (stomatitis, headaches, nervous, etc.).

Local lesions. — The teeth of the majority of workers are blackened, in some almost completely black (when dental toilet is neglected); if dental toilet, on the other hand, is very good then only the portions of the teeth not reached by the brush (at the back and sides) are more or less black. The front and side teeth become brittle and decay or break off easily without, very often, the accompaniment of much pain.

The question arises whether this is a specific action of the fulminate or due to the effect of the nitric acid used and so to be considered as an acid necrosis. The wearing away and brittleness of the teeth are without any doubt due to the slow action of acid vapours present in the atmosphere and can only be got rid of with difficulty (in so far as relates to those employed in heating and washing processes in which, in spite of the best system of ventilation, some fumes — nitric and nitrous — nevertheless hang about). The characteristic blackening of the teeth must be considered as the result of specific action of the mercury (see articles "Mercury" and "Hair Cutting") and is due to the formation of sulphide of mercury which is produced by the sulphuretted hydrogen gas evolved in the processes of decomposition of food in the absence of careful dental toilet. Koelsch detected these lesions in seven out of twelve persons who had been employed for many years (3 to 17) in the processes of boiling and washing. He failed to find them in those newly employed. This condition is observed also, though less frequently, among workmen engaged in the screening of the detonating composition for filling the caps.

The skin in the majority of persons employed in mixing, drying, filling and preparing the composition shows characteristic lesions. The susceptibility of some persons is such that they cannot stand it for a day, others again only suffer in warm weather. Some degree of acclimatisation would appear to set in; but if the number of cutaneous lesions at a particular visit seems to be small it must be remembered that elimination of the particularly susceptible may have been already effected (Koelsch). The frequency of these lesions, however, is pretty considerable; dozens of workers are often engaged until it is ascertained which are the most resistant, and these are kept on at the work, so that perhaps three times as many workers pass through as are needed (Koelsch). Occasionally it has been observed that several workers who may have remained immune for many years suddenly go down without any ascertainable reason.

Generally the uncovered parts of the body are attacked by an erythema accompanied by intense itching, swelling and oedema, particularly on the face, eyelids, neck, behind the ears, and on the forearms.
Papules break out on the inflamed areas and vesicles which frequently develop into bullae and pustules.

A pustular folliculitis develops often on the hairy part of the skin. Small circular ulcers with heaped-up edges form (Legge). If the fulminate attacks the knuckles or the roots of the nails, the ulceration may penetrate to the joint and bone. In severe cases, the lesions take on the character of a weeping eczema (red, exuding, swollen skin, ulceration, and formation of crusts). Exceptionally the whole body is affected. The locality affected in an analysis of 60 cases of dermatitis by the Statistical Bureau of the United States Labour Department worked out as follows: hands 3, eyelids 3, face 5, arms and face with sometimes also the neck and hands 16, forearms and hands 39.

Men are more often affected than women—probably because they take fewer precautions. In an establishment in the United States, there were 32 cases of dermatitis among 1,070 women, that is 2.9 per cent., and 36 cases among 505 men or 7.1 per cent.

Recovery takes place from one to two weeks, accompanied by desquamation. Recurrences are frequent, particularly if the cure has not been complete. Occasionally acute eczemas of different kinds have been observed as well as paronychias with loss of the nails (of the fingers). In particularly careless workers, deep and painful ulcerations have been noted. No permanent affections are known. The cutaneous and conjunctival irritation has been described by German authorities (Roth, Oppenheimer), by English (Collis 1903-1913—in persons employed in drying, mixing and filling caps in spite of all the care taken to keep down the dust—Legge and others), and by American observers (Hamilton, etc.).

The superficial mucous membranes are also irritated (Koelsch) in persons carrying out sieving operations. After a very short stay in the rooms where these operations are carried out, a slight pricking of the eyes and nose is felt with inclination to sneeze and irritation of the throat; occasionally there is marked irritation of the mucous membranes (pharyngitis, rhinitis, conjunctivitis). The workers, before commencing to sieve, are accustomed to stuff their nostrils with cotton wool and to wear a respirator in the effort to prevent the irritation consequent on contamination of the eyes and mucous membranes by dirty hands. Lesions of the skin and mucous membranes are described in persons engaged in decanting, drying, mixing, weighing and transport of fulminate, whether the material is dry or wet. Sweating favours the occurrence of the skin conditions, thus explaining their greater frequency in hot weather. The finer, too, the powder the more powerful is its irritant action.

Curiously enough, workpeople affected by venereal diseases suffer immediately from a weeping eczematous condition on the face.

The definite symptoms of mercurialism require explanation. German authorities describe symptoms of varying severity (Heinzerling gives 40 per cent, as the number of workers affected in a factory in Nuremberg), the symptoms ranging from tremor and excessive salivation to ulcerative stomatitis (Pappenheim), cachexia more or less marked with inflammation of the gums (Eulenberg), etc. Teleky also has described some similar cases among workers in a cap filling factory. During the war (1915) Oppenheim, of Vienna, described slight cases (with detection of mercury in the urine and permanent hypersensitivity) which appeared soon after the commencement of work.

The report referred to previously published by the Medical Inspector of Factories in Great Britain described the presence of a blue line on the gums (a rare observation and present in only two out of 60 workers), digestive disturbance, painful diarrhoea, headache, nervous symptoms, and depression. The last-named symptom is important not only as evidence of poisoning, but also as indicating the need for transference to other work, because a shaky hand and dull mentality are undesirable when dealing with so explosive a substance. The digestive symptoms are no doubt secondary to stomatitis, especially when a dental plate is worn.

Generally the insomnia complained of is secondary to the itching of the skin condition, and this trouble is made worse when the workpeople sleep in the same clothes as are worn at work.

Poisoning may also be caused by mercurial fumes given off when the mercury detonates. Small explosions of individual caps are very frequent in the rooms where charging and compression of the composition are done. The quantities of fumes given off, however, are very small; disseminated in the air of the workroom, often mechanically ventilated, they are hardly perceptible and cause little trouble. Conditions are quite different,
though, for workmen engaged in exploding the caps which cannot be used and those working in rifle ranges where uninterrupted firing produces fumes quickly. French literature has not a few references to cases of poisoning among range attendants due to constant inhalation of fumes given off by explosion of fulminate of mercury (Teleky). In a Bavarian town at a shooting match lasting three days, quite a number of those who participated, particularly the persons in charge of the targets and the staff who spent twelve hours a day in the room with ten galleries (Boesl, 1911), showed symptoms of stomatitis, nausea, vomiting, and colic.

Lastly, it should be mentioned that the water used to wash the fulminate is collected and distilled to recover the mercury. In doing this there is a possibility of mercurial poisoning (some cases have been described), the amount of mercury in these waters being considerable (30 lbs. of mercury from 140 lbs. of deposit left by the washing water).

Mention only need be made here of the frequent accidents in the manufacture and use of fulminate of mercury.

**Diagnosis**

Confirmation is best obtained from the medical history. (For details see article "Mercury"). Treatment follows the usual lines for dermatitis and mercury poisoning.

**Prophylaxis**

Dissolving the mercury in nitric acid should be done in closed receptacles with good exhaust ventilation for the fumes evolved. The other gases given off should be aspirated or condensed, or removed to the outer air well above the heads of the workers. Meticulous attention to detail should be paid in all matters appertaining to cleanliness of the entire plant, not only in the interests of health, but also of the prevention of accidents.

**Personal hygiene** is of extreme importance. Medical selection of workers is called for; those showing skin affections, or having sensitive skins, as well as those addicted to alcohol, should be eliminated, and new employees should be instructed as to danger. Subsequently the workpeople should be kept under observation by a medical man. Workers with skin affections must be immediately removed from contact with the material. The skin should be lightly dusted with powder before commencing work. In the United States (at the Frankford Arsenal) the workpeople coming into contact with fulminate receive carbolised vaseline wherewith to restore softness to the skin after washing. The face and other parts of the body should not be rubbed with soiled hands. Before commencing work in the factory the teeth should have been seen to and made sound. Carious teeth should be stopped, and sharp angles smoothed, stumps and teeth irretrievably decayed should be extracted. Tarter should be carefully removed and the teeth scaled. Smoking should be prohibited. The mouth, teeth, and pharynx should be frequently washed and cleaned with a soft tooth brush and a dentifrice, or well rubbed with cotton wool held in forceps and previously dipped in a disinfectant. The mouth further might be rinsed with an antiseptic and astrigent lotion. The persons employed should be provided with well-fitting overalls, caps, and indiarubber gloves, and, if necessary, respirators. Washing accommodation should be close to the workrooms. Most important is a separate towel for each worker. Daily distribution of milk, if that is possible, might be useful. The employees at the Frankford Arsenal, in order to prevent dermatitis, are given an ointment made of balsam of Peru, oxide of zinc, and a little carbolic acid.

In England, washing of the hands and arms before meals and before leaving, in a 11 per cent. solution of hyposulphite of soda is recommended. Whenever powder penetrates into the skin through an abrasion or cut, use is made of this solution. An eyewash of 2 per cent. hyposulphite of soda solution appears useful. Towels should be changed daily. Substitution of machinery for hand labour is impossible on technical grounds (bearing in mind the nature of the product).

Firing munitions that are not wanted should not be done unless the personnel is protected against the fumes. Use is made of large enclosed furnaces provided with artificial ventilation or similar means. Protection should also be afforded in shooting galleries. In the filling room, where the detonators are filled with the composition, the fumes given off as a result of the numerous small explosions should be removed by mechanical ventilation.

**Legislation**

Adult women are excluded from fulminate factories in France and Japan, and often in other countries where the indus-
try is subject to the regulations of explosive factories. In the province of Quebec (Canada) male young persons under 16 years of age and female young persons under 18, and in France all young persons under 18, are excluded from every room where mercury vapour is given off.

No country has any statutory regulations for the manufacture of furmicide of mercury.

For the preventive measures against fire and explosion, see article "Explosives".

Notification and compensation of cases of mercurial poisoning see the articles "Mercury" and "Occupational Diseases".

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FUR TRADE


Skins of animals, chiefly mammals, with soft silky coats, are tanned and prepared in such a way as to preserve the skin with all its characteristic properties. Such skins provide furs the value of which varies according to the kind of animal or the region from which they come (see article "Hides and Skins").

Furs are mostly obtained from lambs, sheep, camels, beavers, chinchillas, rabbits, foxes, skunks, minks, sables, otters, etc.

The imitation fur trade is to-day very extensive. There are utilised principally the skins of rabbits or other small animals which are dyed and prepared in such a way as to provide a kind of valuable fur.

The fur-producing countries are Russia (Siberia), Canada, North America, and the Scandinavian countries. Rabbit skins are found throughout the whole of Europe and in Australia. The most important fur markets are to be found at London, Leipzig, Nijni-Novgorod, etc.

INDUSTRIAL PROCESSES

Preparation has for its aim, on the one hand, to preserve the natural colour of the fur and to render it glossy and dry, and, on the other, to obtain and preserve suppleness and lightness of the skin.

Large skins are put on the market salted and dried and the small skins are usually merely dried.

One of the best methods consists in stretching and salting the skin, which is then covered with another skin. In Holland, kitchen salt denatured by soda is placed at the disposal of furriers. Where this is not done (in China, for example) the skins are dried in a solution containing arsenic, and then well rubbed with clay containing lime and subsequently dried.

The dried skins then undergo a series of different processes. They are soaked, cleaned, freed from flesh, greased, pressed, dried, shaken, beaten, freed from grease, again shaken and rendered glossy.

For soaking there is used a mixture of waste products from breweries, with a tenth part of acids. With a view to catching and holding the skins more easily, the furrier usually keeps his nails very long.

The skins, after being thoroughly dampened and carded, are submitted to a process in which any parts still remaining dirty are rubbed with a mordant. They are then passed through presses for the removal of any water which they may still contain. In large establishments this is effected by a centrifugal machine, or in small establishments by means of a hand press, while in some cases the operation may even be performed by wringing the fur between two pieces of cloth.

The half-dried skins are sprayed by means of tools with a more or less cutting edge.

In order to extract the grease from the skin and fur, the skins are damped with a solution of alum, then covered with powder composed of products which dissolve fat, such as carbon tetrachloride, trichlorethylene, methyl chloride, etc., and placed at the disposal of furriers. Where this is not done (in China, for example) the skins are dried in a solution containing arsenic, and then well rubbed with clay containing lime and subsequently dried.

Mordanting is carried out in a tanning establishment.

Sheep skins are placed in pairs in a barrel filled with a mordant with the hair to the outside resting on a wooden lattice. A mordant composed of commercial acetic
acid produces the same effects as lactic acid and chrome. The skins are left for twenty-four hours and then the operation is repeated. There may also be used for tanning a solution of alum mixed with different acids, such as picric acid, salicylic acid, formaldehyde, and sometimes even an arsenic solution.

In the case of wild animals, the skins, after being freed from flesh and rubbed with a mixture of kitchen salt and of benzene, have a mordant applied with the naked finger and are subsequently exposed to the air and cleaned. A synthetic tanning substance known as "Nera-

Where stronger skins are in question, there is added up to 2 per cent. of sulphuric acid to a solution of alum and of kitchen salt. Pressing is often effected by means of a hand press operated in a careful manner. The skins stretched on ropes are dried usually in drying chambers and ironed in revolving cylinders.

The beating of skins and of furs has for its object the removal of all dust and the prevention of destruction due to moths.

In fur establishments the skins are stored in cold-storage chambers away from the light and the sun, in order that they may not become heated and with a view to preserving the colour.

Periodical beating is the only effective means known for avoiding destruction by moths.

After manufacture the operation of beating is carried out with a view to removal of any loose hairs and of dust, and at the same time in order to raise the pile of the hair which has become more or less flat during preceding operations.

In furriers' establishments there is effected during the summer season what is known as the fur-preserving operation.

Fig. 117. — Lesions of the nails on the hands of workers engaged in stripping skins of flesh (initial stage thumb and first finger).
of beating several times and replacing in cold storage.

Skins, which usually arrive dressed and finished in furriers' establishments, very often require, however, a final treatment for removal of grease. This is done by coating the skin (when it is new) with beechwood or mahogany sawdust (the latter for coloured skins) mixed with a little benzene, or by coating worn furs with flour or talc powder (the latter when the skin is white or light in colour).

The removal of grease is done by hand that the sides of it consist of metallic lattice work with large spaces. This barrel is then inserted in a closed drum, and a still better arrangement consists of injecting air under pressure, with the result that no dust is liberated in the workroom.

The skins and furs are then placed on trestles and beaten by two men, who stand facing each other armed with canes. Beating machines are also used and with good result, though it has been alleged that they are liable to tear the hair from

with a brush, or more often in a revolving barrel. The sawdust is slightly wetted with benzene or benzol. Often balls of india-rubber are placed in the barrel, which have the effect of rendering the skin slightly more supple.

The skins and furs are thereafter beaten for the removal of loose hair and sawdust or of flour. Very often this operation is preceded by mechanical cleaning effected in a barrel similar to the former, except very fine skins. This disadvantage may, however, always be avoided by reducing the revolving speed. The type of machine in question is similar to that used for beating carpets or sacks. Another type is based on the lines of the hand process described above.

In the case of large skins, after washing with soap and water they are rubbed with grease, ironed and left to swell by means of the addition of chemical products, brain

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Fig. 118 - Lesions in an advanced stage (thumb, forefinger and ring finger).
and a salt solution, which has the effect of facilitating the removal of the flesh. They are then submitted to the action of a solution of salt and alum and thereafter plunged once more into a salt solution, solution with an iron tool having a cutting edge for removing any remaining flesh and cleaned as indicated above.

The treatment of skins with hot soapy water or with an alkaline solution or with carbon tetrachloride or chloroethylene has for its object to render the skins glossy.

Where fine skins are in question, there is used a solution containing glacial acetic acid. In the case of white skins, they are dusted with talc powder and then beaten vigorously.

The skins are, in addition, rendered glossy by treatment with fats, paraffin oil containing especially spermaceti, musk and civet. During this process the skin is rubbed with yolk of egg.

In order to curl the hair there is used pure liquid ammonia and 5 per cent. of gelatine dissolved by heat. The fur is subjected to this solution and then dried under a cloth.

Dyeing of furs has for its aim, on the one hand, to preserve the original colour of the hair, or otherwise to transform the natural colour into some other given colour. Before commencing dyeing processes, the skins have to be prepared in a certain manner; besides the so-called treatment in brine, which is a mixture of kitchen salt and dilute sulphuric acid, treatment by a tanning solution with a basis of alum is used for a certain number of skins and particularly for very fine fur with short hair. The tanning of commercial skins is carried out by means of oxidising fats. There is also used frequently a tanning substance with an alum basis, to which is added formaldehyde, which consolidates the hair and the skin.

Tanning with a chrome basis is used for skins intended as rugs or in the case of a dyeing process which demands high temperature, generally subsequent to tanniny by a substance having an alum basis. Before submitting the skins to the operation of dyeing, any acid which they may contain has to be extracted. If it is desired to render the skin a bad heat-conductor, tanning products of vegetable origin are used. After tanning, the skins are often greased before being put into the drying chamber. They are then passed through damp sawdust and finally dried once more.

The hair is often shaved before dyeing and the coarse hairs removed (bristling, plucking).

In order to prepare the hair for mordanting by means of metallic salts and for dyeing, they are freed from grease or the grease which they contain is emulsified. This operation is known as "killing the hair" (tuer le poil) and consists merely of dipping the skins into a barrel or of brushing them with a solution. In the first method there is used a solution of water or of mix of lime or of ammonia, to which there is added formaldehyde in the case of fine hair or skins with a woolly texture. The coarse hair or skins containing much fat are "killed" by an alkaline solution of soda. The hair side is protected against the effect of the solution by a coat of wax or varnish. After "killing" the skins are rinsed and washed in water acidulated by the addition of a little acetic acid. The process effected in the barrel is carried out mechanically, as is likewise the washing.

In order to free the skins thoroughly from any water which they may contain, they are hand pressed (curled hair) or pressed by centrifugal machinery (brunt hair).

Different shades are to-day obtained in the dyeing industry by means of colours with a tar basis. The shades differ according to the mordant used and the reaction in the dyeing vat.

Metallic salts are used as mordants in dyeing skins, especially with a view to obtaining dark shades; for clear shades mordanting is not necessary. For the following colours: brown, grey-brown, black-brown, as yellow or yel-low brown, there is used bichromate of soda, sulphate of copper and tartar; for red brown and fancy browns there is used a solution of sulphate of copper, sulphate of iron and acetic acid, or of sulphate of copper and acetic acid. Certain colours are applied with a mordant having a chrome or iron basis.

Besides the aniline colours, there should be mentioned as of first importance a series of derived colours, such for example as the hydrochlorides of paraphenylendiamine, para-amidophenol and diamidophenylamine, known in commerce under various names. There may also be used acid dyes with a naphtylamine basis (for sheep's skins), chrome colours, anthracine chrome colours, etc., and as metallic products litharge, oxide of lead, etc.,

The temperature of the bath likewise varies from 20° C. to 25° C., and even up to 35° C. In view of the strong concentration of the mordant in the bath, temperature, it is essential to keep the skins moving in order to obtain a uniform effect. The mordanted skins are afterwards rinsed. Where an acid bath has been used, the water is rendered alkaline by the addition of soda.

The dyeing may be effected by plunging the skins into a barrel containing the colouring liquid or by applying the latter to the skins with a brush. In the first case, the bath is prepared at the requisite temperature, 20° C. to 25° C., and according to the process followed the solution is thereafter cooled and acidified, rendered alkaline or neutralised by adding, according to necessity, formic acid or ammonia.

After cooling and while the fur is still immersed in the bath with the hair side turned downwards, peroxide of hydrogen is added. The tips of the hair and hard hair or bristles are dyed by applying a coating of dye. Two of the processes are, however, at present usually combined. When the
skin of the fur must not be dyed simultaneously, the method of beating is followed; solutions of dye are applied to the dry skins by beating with a hair brush. After dyeing, the skin is rinsed in running water, pressed and dried in a centrifugal machine. The hair is then rendered glossy. The skin is once more coated with a strong solution of alum and kitchen salt and dried in hot air. It is then stretched by hand or by machine, softened and rendered supple by dipping in soapy water, then cleaned with sawdust, dampened, and finally dried. It is thereafter heated to 35° C. in order to give it a brilliant appearance and to fix the colour.

Shaking in sawdust is productive of dust.

Almost all formulae for rendering the fur glossy contain metallic salts, amongst which are found such toxic products as mercury, arsenic and white lead (see those articles).

PATHOLOGY

The handling of skins by trappers, knackers, buyers, transport agents, and furriers, may give rise to the transmission of infectious germs (anthrax, pulmonary plague, etc.). The furrier is likewise exposed to dust given off by the skins (dust of a chemical origin or otherwise).

The most usual diseases of furriers are forms of dermatosis caused by the products utilised for preserving and preparing, etc., such as: arsenic, acids, caustic soda, etc.

The irritant action of these substances is manifested chiefly on the uncovered parts of the skin (hands, arms, etc.), as well as on the mucous membrane of the respiratory passages.
The forms of dermatosis are at times very serious and accompanied by eczema and ulceration. The use of arsenic, salts of mercury, and lead may also give rise to poisoning.

Koelsch and Ilzhofer have reported two cases of lead poisoning (1925) occurring amongst furriers preparing imitation chinchilla fur from Russian rabbit skins. This effect is obtained by the application of a solution of acetate of lead and subsequently of ammonial sulphide which gives off sulphuretted hydrogen, whilst the lead sulphate becomes fixed in the hair.

The ratio of this latter product is augmented in accordance with the darkness of the skin. The lead content varies between zero and 4.62 grm. of lead per 100 grammes of skin.

The most characteristic disease of furriers is, however, certainly that caused by paraphenylendiamine, known under the name of "Ursol". This product, which has been utilised since 1888, is said in the course of the first year to have given rise to asthma in the case of 30 per cent. of German furriers manipulating it. A series of experiments revealed not only cases of dermatosis, which usually attacks the forehead, the face, the hands, etc., with a form of eczema and sometimes with ulceration and subcutaneous cellulitis, but also cases of bronchitis and asthma.

In 1916, Knowles reported a fatal case with somnolence, vertigo, weakness of the lower limbs, epileptic convulsions, loss of consciousness, etc. Leymann met with 187 cases of poisoning from Ursol in a Leipzig factory in the course of one year.

An enquiry effected in 1924, by Rosenbaum, in a dyeing factory for furs at Moscow, as the result of a high incidence of disease due to Ursol, revealed the fact that this product exerts a definite and specific effect on the health of workers (eczema, asthma, hypertrophical rhinitis, bronchitis).

Whilst Curschmann, who has observed several cases of asthma, is persuaded that this lesion is of anaphylactic origin, Hanzlik (1923), in a pharmacological study of certain aromatic diamines, arrives at the conclusion that the asthma and respiratory symptoms caused are due to the direct irritant action of the toxic product rather than to anaphylaxis (see article "Paraphenylendiamine "). Amongst workers engaged in the dyeing of furs, Gilbert has noted an affection which, without causing important lesions, may sometimes, however, diminish considerably the occupational efficiency of the worker. The symptom in question is a disease of the nails, which is rarely met with amongst the numerous workers engaged in tanning, tawing, washing skins for carottling, etc.

The workers engaged in stripping the flesh from rabbit and hare skins present a lesion which begins in the follicles under the nail at the level of which the nail edge becomes detached to a greater or lesser extent. This loosening of the nail is the only painful phase of the disease (see fig. 117).

In the more advanced stages, the nail of the index finger falls off, leaving the bed of the nail exposed. The nails of the middle finger and thumb are changed in appearance, and reduced to an irregular, fungoid and blackened shape (figs. 118 and 119).

This disease, which usually affects to a much greater extent the right hand than the left hand, particularly, the thumb and forefinger, appears to be of microbic origin. It is not accompanied by inflammation and is independent of any alteration of the epidermis.

W. G. Thompson is said to have met with a definite incidence of cases of pulmonary abscess amongst New York furriers (1913), and an enquiry effected in 1915 by the Department of Public Health for the same town, covering 3,839 workers, 542 of whom were subjected to careful examination, produced the following data: 12 cases of asthma, 32 of bronchitis, 11 of pulmonary tuberculosis, 7 of emphysema, 163 of dermatosis, 151 diseases of the nose and throat, 74 of the heart and 89 of the eyes. Only 14 per cent. of those examined were free from physical defects.

In France (1928) Heim de Balzac, Agasse-Lafont and Feil have published the results of an enquiry into the incidence of occupational aniline poisoning carried out in one of the largest fur factories in the world, utilising eighty million rabbit skins per annum (imitation fur trade). Amongst workers engaged in impregnating the skins to the dyes and dyeing them by hand 80 per cent. suffered from headaches and vertigo, 18 per cent. from digestive derangements and 10 per cent. from eczematous lesions. In 10 per cent. of the cases found, anaemia was present and the leucocyte count did not present serious modification apart from a tendency to polynucleosis; the small lymphocytes were almost constantly above the normal.

Amongst workers engaged in the dyeing departments anaemia was found in 20 per cent. of the cases and eczema in 50 per cent. Workers handling the skins suffered from slight, unimportant troubles confined to certain of the workers. Cardio-renal lesions were not met with. The general impression created
as a result of the enquiry is that of the value and efficacy of protection by the adoption of hygienic preventive measures.

**Hygiene**

Progress in colloid chemistry has to-day made it possible to dye skins so effectively that the substance adhering to the hair can only be removed by great difficulty, and that the production of dust particles is reduced to a minimum. The hands may be protected against the irritant action of dust by the use of rubber fingers.

As a method of prevention against injuries due to Ursol, Curschmann has proposed the use of calcium either injected subcutaneously or inhaled.

Frois, who effected an enquiry in 1923 relating to 261 establishments in the Department of the Seine where beating of the skins and furs is engaged in, reports that no statistical data are available in relation to sickness and mortality amongst such workers. It would, however, he asserts, be as difficult to designate this occupation a priori as unhealthy as to consider it free from risk. The operation of beating, from its very nature and because it is generally carried out in basements or in badly ventilated workshops, should be considered as dangerous, especially for young persons and for children.

It is perhaps going too far to insist on disinfection of skins before handling, but as regards furs which have already been worn, it would be most advisable from a hygienic point of view if these were received in special sacks and placed in formol stoves for disinfection before any handling—a practice which does not cause deterioration.

Removal of grease should be effected in a barrel or vat, never by hand, and followed by a cleaning process, also effected in a closed barrel or drum.

Such apparatus should be placed in a separate room, where the staff are not obliged to remain.

Hand beating, which will never be completely given up, should be done outside the workrooms in cases in which it is but rarely engaged in. In large establishments, however, it should be insisted on that this operation should form an exception to the rule and should always be effected in a special, large and well-ventilated workroom. It would be advisable to carry out this operation under an exhaust hood fitted with a suction apparatus or even with a gas jet to assure a slight negative pressure.

Workers engaged in beating would do well to attach a damp sponge to the nose and mouth—such sponges to be, however, strictly personal property and to be cleaned after each operation in a very dilute solution of sublimate. Daily washing-down of the walls and floors of the workroom is essential.

Other measures necessary to the welfare of the worker are: wearing of working clothes—overalls closed at the neck and wrists, gloves; the provision of washing accommodation and cloakrooms, etc., in accordance with hygienic prescriptions.

Besides the effects due to dust produced during beating, quantities of so-called remedies against moths are applied, particularly naphthalene, used in various forms (crystals, powder, balls), and the latter causes smarting of the eyes, headaches, vomiting, and loss of appetite.

Amongst other remedies against moths placed on the market may be mentioned camphor, hexachlorethene \( (C_2Cl_6) \), "Kalo", "Global", "Nova ", products which, according to analysis effected by the Chemical Service of the Dutch Factory Inspectorate, have as their basis paradichlorobenzene.

See also article "Benzene Derivatives".

**Legislation**

In Italy, boys of under fourteen years of age and girls under twenty-one are excluded from beating and cleaning of feathers and furs.

In Holland, the work of women and young persons is only permitted under certain special conditions.

In Russia, the Order of 28 September 1923, in regard to the construction and installation of fur and fleece factories, sets forth a series of measures regarding workshops, temperature, lighting, ventilation and examination of the skins by the sanitary authorities, in addition to conditions in workshops where dipping, dressing, stripping of flesh, tanning, finishing and drying are carried out, as well as restrictions regarding removal of debris from the processes, etc.

Pulmonary diseases occurring amongst workers occupied in the handling of furs and skins are subject to compulsory notification in Holland.

Erysipelas, anthrax, plague and smallpox amongst workers handling animal hair are compensated as accidents in Japan (see also article "Hair, Animal (Bristles")).

**Bibliography**


HEIM DE BALZAC, AGASSE-LAFONT, and FEIL, in *Journal médical français*, 1928, No. 11.


The plates have been kindly lent by Dr. D. GLIBERT (Brussels).

*Dr. Kranenburg*  
(The Hague.)
Gamekeepers, Hunters, Trappers, Breeders, etc.

French: Chasseurs et Eleveurs d'animaux. — German: Jäger und Tierzüchter. — Italian: Cacciatori e allevatori. — Spanish: Cazadores y ganaderos.

The pathology of these occupational categories comprises a general pathology due to a certain number of conditions which they have in common and a special pathology connected with the various causes which come into play in regard to each of the particular occupations.

Gamekeepers, hunters, and trappers are chiefly exposed to fatigue due to the long duration of the hunt, to obstacles encountered, to posture (bent, kneeling, or lying), which sometimes involve special injuries (lumbago, headache due to congestion, epistaxis, etc.). There must also be taken into account exposure to weather which, even after a certain amount of acclimatisation, may bring about discomfort due to heat (headache, congestion) or, more often, diseases connected with cold (catarrh of the eyes, the nose, the throat, rheumatism, neuralgia, gastro-intestinal disease, and respiratory disease), which chiefly affect fowlers engaged in snaring or shooting birds, especially aquatic birds, which involves remaining for long hours in or on the water.

In addition to lesions due to accidents incurred in hunting (injury caused by firearms, by instruments used, by traps, or by the animals in question), hernia is frequent on account of strain and effort as well as ocular troubles due to exposure to bad weather or to the action of foreign particles on the eyes (seeds, blades of grass, caterpillar hairs, etc.). Such lesions, though fairly innocuous, may sometimes become infected and so cause blindness (serpiginous ulcer of the cornea).

In course of the chase workers taking part in it may be bitten by various insects: arthropoda, spiders, chiefly in the tropical regions (mygale of South America for instance), by such insects as bees, wasps or by larvae (processional caterpillars and others, such as Leptus autumnalis, Pediculoides ventricosus, Acarus hordei, Leptus irritans, etc.), which burrow under the skin or enter cracks of the skin and cause irritation and pruritis. Hunters and trappers may also be attacked by various animals (by venom of serpents and vipers and toads, salamanders, etc.).

Gamekeepers and hunters are likewise exposed to troubles connected with sensitisation of the protein and caused by vegetable dust (hay fever, flax dust, etc.) as well as to a great number of infectious and parasitical diseases: malaria, typhoid fever, tetanus, contamination of wounds and abrasions by contact with the ground.

There should also be taken into consideration the fact of irregular hours for meals and for sleep, which often gives rise to various disturbances frequently favoured in their development by the abuse of alcohol. Certain contagious diseases affecting hunters have relation to general hygiene and their modus vivendi (life in huts, table utensils used in common and lack of proper cleanliness, etc., favouring the dissemination of certain germs, typhus, diarrhoea, syphilis, itch, etc.

Breeders (dogs, birds, rabbits, silver foxes, serpents, crocodiles, etc.) often combine this industry with that of hunting (either the same animals or others), and in such case they are exposed to the risks above enumerated. When they are exclusively engaged in breeding, they lead a more sedentary life, which protects them from the injuries above referred to.

Gamekeepers, hunters and breeders are, however, exposed to risk connected
with direct contact with the animals. Usually such risks are peculiar to each kind of animal in question.

Besides mechanical lesions (blows from horns, hooves or tails, etc., bites and stings, etc.), the most important injuries are those arising from infectious diseases transmitted by animals.

The diseases of pigeon fatteners have been described by Dieulafoy, Chantemesse and Widal (1890). These workers are obliged to fatten up in a very short time pigeons which have been sent by rail to the large food markets, and they carry out this task either at certain railway junctions or in the markets themselves on arrival of the large game hampers. They blow into the open beaks of the birds seeds of vetch and of millet soaked in water, which they hold in their mouths. An expert worker can in one day fatten several thousands of birds. These workers often suffer from aspergillosis due to a mould (Aspergillus fumigatus) being inhaled either in contact with the aspergillosis chance, a white lump with caseous aspect of the size of a pea, which often appears on the lower part of the bucal cavity of the bird, or by absorption of aspergillosis spores while chewing grains of vetch and of millet covered with these.

The onset of the disease is more or less marked by one or several slight or abundant haemoptyses. The cough is constant and dry and the patient is affected with violent fits of coughing which later on are accompanied by frothy expectoration, then purulent, blood-stained expectoration. The attack on the constitution in general is manifested by fatigue, loss of energy, and fever. Sounding of the patient reveals signs of pulmonary fever at the outset.

Later symptoms of hollowness are found and sometimes signs of bronchitis and attacks of pseudo-asthma. The evolution of the disease is slow, amounting to several years, with temporary relapses and aggravation of the condition. Recovery by pulmonary sclerosis is the rule, except when secondary infection due to the Koch bacillus intervenes.

There may be mentioned also the condition known as psittacosis amongst breeders of parakeets and parrots. It was recognized for the first time in France in 1892 by Peter at the time of an epidemic which killed 500 parakeets out of 1,000 imported from Brazil. This form, known also as parakeets' typhoid, which affected a certain number of people engaged in transporting and looking after them, has a fairly grave prognosis.

Amongst infections transmissible by animals should be mentioned the following: foot-and-mouth disease, glanders, tuberculosis, actinomycosis, tularaemia and particularly anthrax (see these articles). There should be mentioned in this connection the epidemic of anthrax which occurred during 1926 in the Zoological Gardens in London.

It is also necessary to refer to parasitic infection caused by worms (echinococcus, for instance) or other parasites: wood ticks (Ixodes ricinus) got from dogs, the faithful companions of huntsmen, pigeon ticks (Argas reflexus), bird lice (Dermanyssus avium), the various forms of itch (sarcopetes or Acarus scabiei) transmitted chiefly by dogs, and finally tricophytes due to Ectothrix Tricophyton. The latter may be transmitted by various animals: deer, cats, dogs, birds, etc., passing from the animal to man and later from man to man, the disease being very much more serious in the first case (Kessler). The lesions, consisting of agminated folliculitis, are generally situated on the beard, the nails, or occasionally on the scalp.

There should also be mentioned special risks run by huntsmen and breeders of serpents (bites from venomous reptiles) especially in institutes, such as those of Brazil, for breeding venomous serpents for the manufacture of serums. Venomous reptiles cannot be tamed, though from earliest times there have existed snake charmers who have succeeded in controlling them.

Data are lacking in regard to the special risks run by hunting shops, another form of occupation currently engaged in.

### Garages

**Sources of Danger and Pathology**

Work in garages and motor-car repairing shops may give rise to various dangers, of which the most important will be cited here.

The exhaust gases from motor-cars contaminating the atmosphere of workshops may constitute a serious source of danger for the health, and even the life, of persons employed in enclosed workshops.

These gases contain not only a high proportion of carbon monoxide, but also irrespirable gases such as carbonic acid gas, which make their effect
greater than if carbon monoxide alone was present. The exhaust gases are not less harmful, indeed, than is lighting gas, of which the dangers, however, may be avoided owing to the fact that its presence can be detected from the empyreumatic substances present in it and which are often lacking in exhaust gases from engine-running.

The quantity of carbon monoxide contained depends on different factors: type of motor, method of working, etc. Summing up the data available and the researches made, the conclusion can be reached that with the most perfect combustion and most perfect action of the engine (at full load) the exhaust gases still contain 0.2-0.3 per cent. of carbon monoxide; with a diminution of the load and imperfect combustion this percentage increases until, when the car is stationary and the engine running, it reaches proportions varying from 1.4 to 10 per cent. Under very unfavourable conditions proportions of 15 per cent. have been found (Rumpf).

The content in carbon monoxide also varies with the fuel used reaching its maximum with pure petrol. The following table shows the proportion of oxygen, CO₂ and carbon monoxide in the gases formed, according as to whether the engine is supplied with benzene, petrol or a mixture of these substances (Maetje):

<table>
<thead>
<tr>
<th>Experiments (large engines of the Hanomag type)</th>
<th>Fuel</th>
<th>Load</th>
<th>Nozzle of throttled diaphragm</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Shut Cm/m.</td>
<td>Normal Cm/m.</td>
</tr>
<tr>
<td>1.</td>
<td>65 vols. benzene and 33 vols. petrol</td>
<td>8.5 h.p. with 2,450 revs</td>
<td>0.5</td>
<td>0.75</td>
</tr>
<tr>
<td>2.</td>
<td>Ditto</td>
<td>0.6 h.p. with 1,000 revs (running free)</td>
<td>0.5</td>
<td>0.75</td>
</tr>
<tr>
<td>3.</td>
<td>Ditto</td>
<td>Ditto</td>
<td>0.7</td>
<td>0.85</td>
</tr>
<tr>
<td>4.</td>
<td>90 vols. petrol + 10 vols. benzene</td>
<td>Ditto</td>
<td>0.5</td>
<td>0.75</td>
</tr>
<tr>
<td>5.</td>
<td>Benzene</td>
<td>Ditto</td>
<td>0.5</td>
<td>0.75</td>
</tr>
<tr>
<td>6.</td>
<td>Petrol</td>
<td>8.5 h.p. with 2,450 revs</td>
<td>0.5</td>
<td>0.75</td>
</tr>
<tr>
<td>7.</td>
<td>Ditto</td>
<td>Running free</td>
<td>0.5</td>
<td>0.75</td>
</tr>
</tbody>
</table>

The quantity of carbon monoxide in the exhaust gases varies with the state of combustion as well as with the relation existing in the gaseous mixture between the quantities of air and fuel. So long as there is free oxygen in the exhaust gas the quantity of carbon monoxide is at a minimum. But before the oxygen has completely disappeared carbon monoxide is present in appreciable quantity, and its amount increases with the richness of the gaseous mixture. The following table shows the diminution in the oxygen content, the increase in the amount of carbon monoxide and the power developed according to the richness of the gaseous mixture (Harridge).

<table>
<thead>
<tr>
<th>Parts of air to 1 part of fuel</th>
<th>Power developed</th>
<th>Amount of O₂ per c.c.</th>
<th>Amount of CO per c.c.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.9 0.9</td>
<td>rapid</td>
<td>9.8</td>
<td>7.6</td>
</tr>
<tr>
<td>2.1 0.5</td>
<td>increase</td>
<td>15.0</td>
<td>4.8</td>
</tr>
<tr>
<td>1.8 0.1</td>
<td>slow</td>
<td>19.1</td>
<td>3.8</td>
</tr>
<tr>
<td>1.5 0.8</td>
<td>increase</td>
<td>23.5</td>
<td>1.1</td>
</tr>
<tr>
<td>1.0 0.4</td>
<td>increase</td>
<td>28.5</td>
<td>0.6</td>
</tr>
<tr>
<td>1.0 0.2</td>
<td>level</td>
<td>33.5</td>
<td>0.4</td>
</tr>
<tr>
<td>0.9 0.0</td>
<td>fall</td>
<td>38.5</td>
<td>0.2</td>
</tr>
<tr>
<td>0.9 0.6</td>
<td></td>
<td>43.5</td>
<td>0.0</td>
</tr>
<tr>
<td>0.8 1.2</td>
<td></td>
<td>48.5</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Thus when the maximum power is furnished by an engine it is accompanied
by escape of carbon monoxide gas. The actual fuels in use yield a gaseous mixture relatively small when cold and at low speeds, but one which gets richer and richer the faster the engine works and exhausts itself. It follows that if the carburettor is regulated to yield, when the motor is cooled, a mixture which ignites well and allows the maximum power of the engine to be obtained, this mixture is too rich when the engine is hot. This explains why ordinary cars discharge exhaust gases containing 4 to 10 per cent. of carbon monoxide (Hartridge).

Recent investigations have shown that a small motor-car produces about 0.50 c.c. of carbon monoxide gas per minute, while a large car produces twice as much or even more. When such an engine is started up on a cold day in a garage with the doors closed, then the atmosphere, if the place is just large enough to hold the car, becomes poisonous in five minutes (25 parts of carbon monoxide per 10,000 of air), and can prove fatal in ten minutes. The danger is insidious, as the presence of the toxic gas only shows itself on the appearance of the first symptoms of poisoning. The victim feels his legs give way and falls down without being able to raise himself. Consciousness may be lost in a few minutes, and unless assistance is immediately available, the poisonous gas, accumulating as it does as a consequence of the engines working, soon proves fatal. The amount of oxygen in the air which can no longer support the life of the poisoned person is sufficient to maintain combustion in the engine and, indeed, beyond what would be a fatal dose of the asphyxiating gas. The danger, when the car is stationary and the engine is allowed to run, should be insisted on because the combustion of the fuel is incomplete and the quantity of air in the explosive mixture insufficient. Further, when the engine is set to run slowly, either for a trial or for entering or leaving the garage, the emission of exhaust gases is such as rapidly to ensure its diffusion into the surrounding air. In closed garages with the engine running, a content of 2 per cent. carbon monoxide is very quickly reached, and air already containing 0.2 is dangerous. Theoretically it should be possible to remedy this by improved construction of the carburettors, but even with the special adjustments for allowing motors to run free, the amount of petrol is still too high to enable it to be burnt by the quantity of air available under these conditions (Maetje).

The experiments of the General Bak-

<table>
<thead>
<tr>
<th></th>
<th>At a height of 10 cm. above the root of the car</th>
<th>At a height of about 1 m. above garage floor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal exhaust</td>
<td>7</td>
<td>1.3</td>
</tr>
<tr>
<td>Vertical exhaust</td>
<td>16.4</td>
<td>4.3</td>
</tr>
</tbody>
</table>

In maintaining ventilation by ordinary means (aspirating fans?) the respective values of the carbon monoxide were as follows:

<table>
<thead>
<tr>
<th></th>
<th>Above the root of the car</th>
<th>At about 14 m. above garage floor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal exhaust</td>
<td>7.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Vertical exhaust</td>
<td>3.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Ditto, under the fan</td>
<td>0.7</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Certainly, private garages because of their dimensions, the impermeability of their walls and the confined space, are very dangerous from the point of view of the risk of poisoning. In public garages the conditions are less dangerous to life, but they are nevertheless unhealthy. This is true especially in the case of new buildings, as they are closed in, in contradistinction to the old type which allow of a certain amount of ventilation (Henderson and Haggard).

Inquiries conducted in garages in large American cities have shown that the amount of carbon monoxide in the air was on the average considerable. Thus of 102 analyses made in twenty-seven garages in fourteen cities, the proportion of this gas was shown to reach an average of 2.1 per 10,000 parts of air. In more than one-half (59 per cent.) the proportion of carbon monoxide was over 1 per 10,000 and in 18 per cent. exceeded 4 per 10,000 (Bloomfield and Isbell).
In repair workshops the conditions are even worse, and the workmen regularly leave off work with headaches. In some of them work is so arranged that testing the engine is only carried out shortly before closing-time, in order to reduce to a minimum the presence of exhaust gases. The regular inhalation of carbon monoxide has been held to be a probable cause of a large number of accidents at work and on the road. Thus it is alleged that a man who has inhaled carbon monoxide during a period in which the air of garages has his sense of judgement dulled and may suffer from inco-ordination of movement comparable with that of a tipsy man.

The risk of intoxication by exhaust gases is nil in the open. On the other hand, it can take place in tunnels under rivers and among workpeople employed in excavation and at trial benches in factories and workshops.

Winter is the time for accidents to be most frequent as doors and windows are usually kept shut.

The escape of exhaust gas and of gas from the casing in the inside piping is another source of poisoning, and even the use of radiators and foot warmers operated by exhaust gases (Hartridge).

According to Prussian statistics drawn up by Schmidt, of 242 deaths which occurred in 1926, 91 per cent. were due to exhaust gases from engines running in garages (Hartridge).

According to Prussian statistics drawn up by Schmidt, of 242 deaths which occurred in 1926, 91 per cent. were due to exhaust gases from engines running in garages (Hartridge).

In the first two months of the winter of 1926-1927 in Hanover, quite a series of intoxications from carbon monoxide were caused by the exhaust gases from engines running in garages: two of them proved fatal (Maetje).

Rumpf describes seven cases of poisoning as occurring in Germany in the early months of 1928, two of which related to the occupants of motor-cars.

Gowers in 1908 reported a case of supposed petrol poisoning, but which A. Hamilton considers should be ascribed to carbon monoxide. The case was that of a workman employed in looking after petrol engines inside a building. The symptoms of poisoning developed rapidly, disappeared when he left off work, only to reappear on resuming. During a period of six months the patient was affected with a perverted taste (sugar appeared to him salted), then with a sense of constriction at the moment of swallowing, which increased in intensity and obliged him to have recourse to liquid food. He did not complain of regurgitation. His voice was weak and his mental powers were dulled. He had difficulty in speech, and interminable headaches. He complained of dizziness.

As a result of this case, attention was called to the bad habit of employing petrol to clean the hands and arms soiled by walking and the muscles of the eyelids were weak; the reflexes and electrical reactions, however, were normal.

MacNally has described sixty-three fatal cases occurring in garages in Chicago between 1919 and 1926. According to the results of an enquiry undertaken in 1,308 garages and repair workshops in the State of New York 113 cases of asphyxiation took place in the course of two years. Of these 1,308 garages, only 36 were adequately ventilated by means of piping attachable to the exhaust pipes and discharging the gases directly to the outside.

Another source of industrial poisoning in garages arises from benzol, which is often the necessary fuel in certain types of engine. Thus, for example, a fuel used in the United States has the following composition: benzene, 69; toluene, 15.5; light naphtha, 13.5; heavy naphtha, 2.

It is, however, only necessary to have two or three parts of benzol per 10,000 of air aspirated over a few hours to produce unconsciousness (Lehmann). In garages benzol poisoning usually takes the chronic form. The patient complains of headache and nausea, suffers from vomiting and subcutaneous haemorrhages. Fainting and vertigo are not infrequently caused by the anaemia due to the destructive action of benzol on the constituents of the blood. Further, benzol can exert its harmful effect when used as a cleansing liquid. A fatal case has been reported from the use of impure benzol.

In other cases petrol vapour rendered impure with hydrocarbons of low boiling point has been incriminated (Rambousek).

Cases of poisoning from petrol vapour only in garages have been very rare, although its possibility cannot be excluded. Johnson in 1913 reported an instance of massive poisoning, involving forty-two workmen, in a tunnel where a petrol locomotive was being used for the removal of the excavated material (A. Hamilton). The absence of carbon monoxide in the blood of the victims and in the air of the tunnel, and the presence, on the other hand, of petrol vapour in the latter, sufficed to settle the point. Further, the gases may contain unburnt petrol. The symptoms in this case are not unlike those of carbon monoxide, the only difference being that congestion and cardio-respiratory acceleration such as are met with in carbon monoxide poisoning, are absent (Hartridge).
The question in practice, however, is whether these reactions really do take place. The reply rather is in the

symptoms varying according to the substances in question.

It should be recalled that, in repair work, the attitudes which the body has to assume (in pits, underneath the car with the head in a strained position, etc.), uncomfortable or distressing as they must be, induce various forms of cramps and curvatures. In other operations the workmen are exposed to injuries of the most varied kinds, such as Collis's fracture of the radius following faulty turning of the handle in starting.

 Mention should be made also of the risk of explosion as the result of the formation of explosive mixtures (petrol and air), risks which are, however, much less frequent than are generally believed.

The introduction finally of new fuels ("National Fuel") having a basis of alcohol and the use of generators applied direct over the chassis may, in the near future, bring about a new form of accident for workmen in garages and chauffeurs.

HYGIENE

From all that has been said, pollution of the air in garages, and especially from carbon monoxide, emerges as the great danger to the persons employed. Preventive measures therefore must be adopted and knowledge of them must be widely disseminated: adequate ventilation especially in private garages; wide opening of doors and windows or use of installations allowing the exhaust gases from every car to be carried direct to the outside air.

The personnel should be instructed as to the utility of the ventilating arrangements and as to the consequences which may follow if they are neglected or hindered in their application.

In the majority of cases the fan ventilation installed is far from being effective. In order to be effective it should enable the air in the garage to be renewed completely every five minutes. But in winter time, just when it would be most necessary, it is impracticable as it would make the inside temperature the same as the outside.

Sometimes ozone generators are installed with the object of neutralising the carbon monoxide given off by the engines. Theoretically this measure is justified by the following chemical reactions:

$$\text{CO} + \text{O}_2 = \text{CO}_2 + \text{O}_3$$

$$3 \text{CO} + \text{O}_2 = 3 \text{CO}_2$$

The question in practice, however, is whether these reactions really do take place. The reply rather is in the
negative, chemists being of the opinion that if a reaction does take place it is so slow as to be negligible (Salls). And it may even be questioned if the ozone thus given off may not itself constitute a source of damage to workmen (by irritating the respiratory passages: Kranenburg).

Similarly, a recommendation should be made not to allow the engines to run when the doors of the garage are closed; to avoid all repair work on motor-cars necessitating a prone position when the engine is running; to post up warning notices in the garages; to organise well-equipped first-aid arrangements, including provision of oxygen and carbon dioxide cylinders which should be periodically examined (Burnham).

Finally, particular attention should be directed to the provision of really good washing accommodation so as to allow the men to leave off work clean.

**LEGISLATION**

Legislation (hygiene, compensation for industrial disease, etc.) is the same as that for chauffeurs and mechanics.

In Germany (Prussia) the regulations for the construction and installation of garages prescribe — so far as their ventilation is concerned — that every place for a car should be provided above the floor with openings for ventilation of at least 400 sq. cm. Further, the doors must have openings or slots of at least 5 cm. in diameter. The district authority of Hanover requires the use in garages of piping, one end of which is adjusted to the discharge pipe for the exhaust gases while the other end is to be led to the outside through an opening either in the door or the wall (Maetje).

In Switzerland (Boste) an Order of May 1928 makes rules for garage keeping and for repair shops.

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**Statistics**

According to Gerbis, statistical returns for the Sickness Fund of German Gardeners in Hamburg gave, for a period of fifteen years (the years are not indicated), 1,624 deaths classified by age groups and by causes of deaths: for the age group "up to 25 years" there were, in a total of 412 deaths, 120 due to pulmonary tuberculosis, 33 to respiratory diseases, 33 to diseases of the digestive apparatus, 33 to diseases of the musculoskeletal system, 33 to injuries, and 33 to other diseases.

**Gardeners and Market Gardeners**


The working conditions of gardeners are to a certain extent more trying than those of agricultural labourers. The work, in fact, is carried on throughout almost the whole winter, without interruption during bad weather or fog.

The occupation of gardener demands quick intelligence, skill and a highly developed artistic sense.

It is a great mistake to choose for this occupation young persons with weak lungs or those suffering from cardiac or kidney disease.
diseases of the circulatory system and 38 to infections. These various causes of death are represented for the age group "26-35 years" by the following figures respectively: out of 296 deaths, 107, 18, 26, 25 and 20; for the age group "36-45 years" out of 333 deaths: 96, 27, 37, 119 and 10; for the age group "46-55 years" out of 297 deaths: 63, 37, 41, 52 and 12; for the age group "56-65 years" out of 177 deaths: 24, 23, 25, 43 and 6; and for the group "members over 65 years of age", out of 109 deaths: 11, 13, 11, 42 and 1, due to the above-mentioned causes.

According to the above data, relative and absolute mortality was highest up to the age of thirty-five, the maximum occurring between twenty and thirty years of age. In the age group "35 years", tuberculosis and other pulmonary diseases constituted 41.9 per cent. of all causes of death, and internal maladies including influenza and other infections 40.25 per cent.

In the annual report of the Sickness Fund for German Gardeners it is mentioned that a third of the cases of death are due to tuberculosis (Lehmann). As regards diseases due to cold, the Sickness Fund of a large gardening establishment gives for a period of three years the following values (per 100 cases of sickness from all causes):

<table>
<thead>
<tr>
<th></th>
<th>1920</th>
<th>1921</th>
<th>1922</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workers working in</td>
<td>33.3</td>
<td>37.3</td>
<td>29.7</td>
</tr>
<tr>
<td>the fields</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other members of</td>
<td>3.5</td>
<td>5.5</td>
<td>4.7</td>
</tr>
<tr>
<td>the Fund</td>
<td></td>
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</tbody>
</table>

Incacity for work due to affections connected with cold showed the following values for 100 insured members of the two above groups:

<table>
<thead>
<tr>
<th></th>
<th>1920</th>
<th>1921</th>
<th>1922</th>
</tr>
</thead>
<tbody>
<tr>
<td>Members working in</td>
<td>12.6</td>
<td>12.7</td>
<td>12.3</td>
</tr>
<tr>
<td>the open air</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Members occupied in</td>
<td>1.7</td>
<td>2.3</td>
<td>2.2</td>
</tr>
<tr>
<td>transport, store-room work and office work</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

English mortality statistics for the period 1921-1923 show values which would appear to prove that gardeners are less subject to different disease forms than the total number of occupied and retired males, except perhaps to appendicitis. In fact, whilst the mortality from all causes is 1,000 for occupied and retired males, it only amounts to 707 for gardeners, and that from tuberculosis (all forms) to 134.5 as against 177.3; that from respiratory diseases 122.8 as against 163.5; that from heart disease 101.7 as against 129; and that from valvular disease of the heart 34.1 as against 62.4.

**PATHOLOGY**

Gardeners are exposed to heat-stroke as well as to the effects of all kinds of inclement weather. Often they work during long hours without being able to change their wet clothes, which fact predisposes them to respiratory diseases and affections due to cold.

Digging, scattering manure, watering, long working hours, hard work in the hot damp air of hot-houses, explains the relatively high number of deaths from tuberculosis, especially in the first years of occupation; tuberculosis attacks at an early stage the weakest individuals.

In winter gardeners suffer from sudden changes of temperature (sudden passage from 28°C. of heat in hot-houses to the outdoor cold).

Work in a kneeling position for planting, uprooting of weeds, pruning, etc., gives rise to localised forms of rheumatism, especially in the knees; cress, which is cultivated in small artificial canals, is difficult to gather; the gardener works on a small bench placed across the canal and is obliged to remain for a long time in a tiring position when engaged in this operation.

Gardeners are also exposed to injuries which are often serious and sometimes even fatal, due to stings and bites of insects — mosquitoes, wasps, bees, etc. Workers engaged in sorting and cleaning seeds are exposed to dust inhalation, though it must be remembered that this work only lasts for some weeks during the year.

The pollen of certain plants causes hay fever characterised by irritation of the ocular and nasal mucous membrane and sometimes by asthma.

Handling of manure, amongst the least harmful kinds of which is horse and cow dung, but which also consists at times of night soil, may constitute a cause of various types of infection: typhoid fever, cholera, dysentery, etc. Tetanus is easily contracted as the germ of this disease inhabits the soil, and gardeners often contract the bad habit of applying earth to their wounds in order to stop bleeding. A fatal case of tetanus was reported in 1928 in Geneva as affecting a gardener who had been scratched by the thorn of a rose.

Aspergillosis, sporotrichosis and actinomycosis have been reported amongst gardeners handling contaminated plants. Foester (United States) noted, during the period 1920-1925, 14 cases of sporotrichosis amongst gardeners en-
gaged in nurseries. Efforts succeeded in isolating the sporotrix on the bark and thorns of bushes of barberry. Out of 145 cases of sporotrichosis reported in the United States, 17 affected gardeners. Other cases have been reported, particularly in France.

There are many plants which are capable of setting up localised dermatitis, in general on the hands, forearms, face and more rarely on the genital organs (Timpano). All parts of the plant are not equally dangerous. The nettle, for instance, causes a mechanical injury due to small hairs which become detached from the plant and constitute small needles which serve to inject the poison into the skin. The time of day and the amount of humidity may in certain cases exercise an influence. Thus the pruritis may be more harmful at the moment when it is highest (Timpano). The time of incubation varies: some hours to several days, e.g. in the case of the Japanese primrose. This plant (Primula obconica) was imported from China to the United States in 1882 and the first case observed was that of a florist who suffered from its effects in two consecutive years at the same time of year (Kober). Certain individuals are so sensitive that the least contact with the hairy parts of the plant suffices to provoke eczematous dermatitis. According to certain authors it is the crystals of oxalate of calcium contained in the plant which act as a means of conveying the poison (Lewin, Hoffmann), whilst others consider that the crystals themselves are precisely the cause of the dermatitis (V. Schorff). According to Lehmann, 30 per cent. of the gardeners who cultivate this plant suffer from it.

Other plants are at times the cause of dermatitis and conjunctivitis amongst gardeners: the "sumac" (Rhus toxicodendron), the resin of which contains a poisonous product giving rise to forms of dermatitis midway between eczema and erysipelas: mezereon (bois gentil, bark of Dvaine mezereum),celandine, bulbs of hyacinths and tulips; the Ampelopsis quinquifolia, which causes, especially in autumn, violent irritation of the skin localised in the hands, the face and the back of the neck (Harrison); arnica, vanilla, geranium; asparagus (Schoenhoff, 1924; Sternberg, 1925); virginia creeper (Lyvett 1891); the Arundo donax (Timpano, 1921); the "may weed" (Sequeira, 1921), celery (Lortat, Jacob and Legrain, 1926; erythemato-bulbous dermatitis of the hands and forearms when in direct contact with the juice of celery; relapse on resumption of work); the lemon, the orange, etc. Finally, the dust of cereals provokes a kind of urticaria of a papulous type on the parts exposed, often intensified by exposure to light (Rible).

In 1926 it was reported in Jersey and the Scilly Isles that people handling narcissus, hyacinths, wild daffodils and tulips were suffering from dermatitis. An enquiry made in two largest establishments exporting the bulbs of these flowers resulted in the discovery that a small percentage of the sorters and packers were suffering from painful lesions with desquamation of the skin localised entirely under the nails (peri- and hypo-nychium, without the substance of the nails being affected). The dermatitis appeared after some days of work and was attributed to the tulip bulbs. Injuries caused by narcissus bulbs were not fatal, but the phalanges of the fingers, the skin of which came away in scales on the slightest rubbing. It was noted that those persons who had the longest nails were the most severely affected (Overton).

Irritation of the skin may also be caused by mites (Acarus) which live from July to October on certain plants such as green gooseberries. On the other hand, gardeners who remove the scoons of night moths (Uproctis chrysorhoea) from trees in the months of May and June have been known to suffer from dermatitis and erythematous patches, or patches of urticaria, characterised by itch, which is sometimes very violent (Prosser White).

Scratches and small wounds caused by thorns may give rise to inflammation of the cellular tissue and, where suppuration follows, abscesses and whitlows. According to the statistics of the Erfurt Sickness Fund, 11 per cent. of the cases of sickness amongst gardeners were due to infected wounds. There must not be omitted also the mention of debris of plants, which, together with earth and moulds, may lodge in the worker's hair and under his nails and finally give rise to phenomena of irritation.

Curling, quoted by Oliver, records that soot, which is used by gardeners to destroy slugs, was perhaps the cause of cancer localised on the back of a gardener. Contrary to Aschoff, who found a very high percentage amongst gardeners, Loth was not able to find one case of cancer during a period of several years. The Sickness Fund for German gardeners reported 5 cases of cancer out of 100 deaths in 1912. In the United States, the statistics of the
Prudential Insurance Company show for gardeners during the period 1907-
1912 a cancer mortality of 8.43 per cent. as against 5.49 for the general popu-
lation (Kober and Hayhurst). English statistics for the period 1921-1923 give
the following figures for tumours (mortality value, compared with the
standard population): 128.4 for all occupied and retired males; 113.6 for
 gardeners; 93 for farmers; 89.7 for agricultural workers, and 95.7 for
wood-cutters.

It should, however, be noted that the
gardeners most affected with cancer
were aged forty-five years and over,
and that the highest figures were found
amongst those aged sixty-five years
and over.

Handling of hyacinth bulbs may also
cause conjunctivitis, which Zeeper (of
Haarlem) attributes to the crystals of
oxalate of calcium contained in the bulb
of this plant.

On the other hand, a serious form
of conjunctivitis (Ophthalmia nodosa)
may be caused by the hairs of cater-
pillars. In certain cases these hairs,
which are very fine, penetrate into the
cornea of the iris and there cause
lesions of such a serious order that
they may sometimes result in blindness
(Gerbis).

For some years back ether has been
used to accelerate the early blossoming
of flowers. It is therefore neces-
sary to take into account the risk in-
volved by the handling of this dan-
gerous product.

Handling of artificial manures con-
stitutes a further source of risk (see
article "Artificial Manures").

Pulverisation of arsenate of lead,
Paris green and sulphate of lead as
insecticides has sometimes caused
cases of poisoning. For some time
back there has been used, especially
in Germany, powdered products based
on mercury and arsenic compounds,
the handling of which demands the
greatest care.

The use of powdered sulphate of lead,
which is very extensive in the United
States, is not permitted in Germany
on account of its toxicity.

Finally, there should be mentioned
the risk of accident, particularly during
work in nurseries.

HYGIENE

Catching cold should be avoided
as far as possible by wearing clothes
adapted to the climate and the
seasons. Working bare-footed should
be prohibited; measures similar to
those provided for agricultural work-
ers are required in the case of

large-scale industry (habitations, etc.).

Effective protection of the worker and
the use of suitable apparatus in the

case of handling anti-parasitic toxic
products is recommended. Individual

cleanliness, especially of the hands,
adequate installations enabling the

gardener to cleanse their hands from
soiling with manure, disinfectant pro-
ducts, etc., should be provided. Prompt
disinfection (with tincture of iodine)
and application of an antiseptic dress-
ing are to be recommended in all cases
of wounds and even superficial pricks,
etc. It is recommended that those who handle
hyacinth and tulip bulbs should cut
their nails as short as possible and rub
their fingers before commencing work
with a piece of common soap. The
wearing of gloves and finger-stalls
is also to be recommended.

LEGISLATION

Compulsory notification has been en-
forced in the Netherlands for diseases of the
skin (eczema, dermatitis) affecting work-\ners engaged in horticulture and the fol-
lowing occupational diseases which come under the insurance scheme for oc-
cupational diseases which covers agricul-
tural workers. In any case, infectious dis-

eases such as tetanus, anthrax, etc., are
mostly covered by accident insurance.

In Germany, the Police Order of 8 Sep-
tember 1925, regarding the use of toxic pro-
ducts for the protection of plants, contains
prescriptions relative to the following
three categories of products:

(1) Products with a basis of arsenic and
its compounds, of nicotine and its
compounds, of compounds of mer-
curry, of salts of uranium (soluble in
water).

(2) Salts of chrome and their com-
pounds and oxalates.

(3) Soluble compounds of barium, so-
luble salts of hydrargyrum, formalde-
yde solutions (of over 4
per cent.), carboxylic acid (more than
2 per cent.), fluosilicic acid (more
than 15 per cent.), soluble salts of
fluosilicic acid, cresols (more than 1
per cent.), salts of oxalic acid, car-
bon disulphide, salts of zinc.

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### Gases and Fumes

**French:** Gaz et Vapeurs. — **German:** Gas und Dämpfe. — **Italian:** Gas e Vapori. — **Spanish:** Gases y Vapores.

**General**

In modern industry gases and fumes may be liberated in considerable quantity either from raw materials or as by-products in course of different processes or at times by the finished product. It is for this reason that the risk of inhaling gases and fumes foreign to the nature of pure air has become increasingly extensive. A classification of gases from the chemical point of view does not provide a means of determining their harmful action on the system. Gases which differ from a chemical point of view — for instance, hydrogen and nitrogen — are identical as regards their physiological action, whilst other gases belonging to the same chemical group have a radically different action on the system. Neither can the classifications usually employed in pharmacology and toxicology be employed as the basis for classification relative to industrial hygiene. Whilst the pharmacodynamic action of a substance is very useful to know, a classification according to this action is of no interest from the point of view of the preventive measures to be taken in order to avoid its absorption or accelerate its elimination.

According to Henderson and Haggard, injurious gases and fumes may be classified as follows:

1. **Asphyxiants.** — This group comprises volatile substances producing anoxaemia or a similar condition due to the fact that they hinder utilisation of oxygen by the system. It is characteristic that these gases attain their object without any direct action on the mechanism of respiration and that they do not exert a directly harmful action on the lungs. This group comprises simple asphyxiants and chemical asphyxiants:

   (a) **Simple asphyxiants** are gases which may be chemically active substances, but which, from the physiological point of view, are completely inert. Their action consists in excluding oxygen from the lungs.

   (b) **Chemical asphyxiants** are gases possessing certain specific properties which render them asphyxiant, even when they only exist in reduced quantity in the atmosphere. Their action does not consist in excluding oxygen from the lungs, but in an effect on the blood which is rendered incapable of transporting oxygen, despite good ventilation of the lungs. They may further prevent the tissues from absorbing oxygen, though the latter may be supplied in sufficient quantity by the blood.

2. **Irritants.** — Gases of this category are substances which, from a chemical point of view, may be considered as corrosive agents. They attack the superficial layers of the respiratory passages and cause inflammation of the bronchial tubes and of the lungs. The effects of irritant gases differ considerably, chiefly on account of their varying solubility coefficients. For this reason, gases of this category can be easily arranged in a scale of solubility.

3. **Volatile and similar substances.** — Fumes exercise a very slightly specific action on the lungs, but take effect after having been absorbed by the blood and transported to the tissues. Their acute effects operate chiefly on the nervous system by inducing anaesthesia.

   This category comprises a large number of volatile hydrocarbons occurring in industry, whose chief action is essentially like that of the substances used for surgical anaesthesia, and also the organic nitro compounds whose more characteristic action is to alter or destroy the haemoglobin.

   Finally, volatile nitriles such as amyl nitrite exercise a dilating action on the blood vessels and lead to collapse.

4. **Inorganic and organometallic substances.** — Without exercising a direct action on the lungs, their harmful effect is produced after absorption by the system. They are gases and fumes containing phosphorus, mercury, lead, etc.

**Physical Laws**

A knowledge of the physical laws governing the behaviour of gases and fumes is of particular value for comprehension of their physiopathological action.

Gases and fumes are present in the surrounding atmosphere to a certain degree of concentration which may be expressed in various ways:

- (1) per cent. per volume;
- (2) parts by volume;
- (3) partial pressure;
- (4) weight per volume (milligrams per litre of air).

Each of these methods of measuring is capable of being converted into any of the other forms and possesses advantages of application for particular circumstances.

The “partial pressure” and the form of expression of “percentage by volume” are generally used to designate the concentration of the common respiratory gases (oxygen, nitro
gen and carbon dioxide) and relatively inert gases, such as methane and hydrogen, the presence of which is only dangerous in very high concentration.

Expression in the form of "part per volume" or "parts per 1,000" or "10,000", etc., is employed to give the concentration of more actively toxic gases. Recently in the United States the form "parts per 1,000,000" has been generally adopted. The disadvantage of this method is that it does not afford a true basis of comparison of the toxicity of the various volatile substances, except when they have nearly the same molecular weight.

The expression of "concentration by weight" of the volatile substances is generally expressed as "milligrams per litre of air". This method affords not only a ready means of comparison of the toxicity of the various substances, but also the best means of estimating the rate at which the air is vitiated, or the rate at which a gas or vapour is absorbed in the lungs.

One gramme molecule of any gas occupies the same volume as one gramme molecule of any other gas, under the same conditions of pressure and temperature. That is to say, that equal volumes contain the same number of molecules and that the weights in grammes are in the same relations as the molecular weights of the substances. At 0°C. and 760 mm. this volume is 22.4 litres. The weight of one litre of any gas at 0°C. and 760 mm. is therefore the gramme molecular weight divided by 22.4. At other temperature and pressure, the weight of one litre of gas is modified according to the laws of temperature and pressure expressed by the formula:

$$G = \frac{(P - V) \times (273)}{760 \times (273 + T)} = G'$$

where $G$ expresses the weight of a litre of a given gas at 0°C. and 760 mm., $G'$ the weight of a litre of gas at an altered temperature and pressure, $P$ the altered pressure, $V$ the surrounding humidity (steam), and $T$ the altered temperature.

The weight of a unit volume is important in expressing the concentration of various gases in air. An expression of this type is readily converted into percentage or volumes of the gas in question; it is sufficient to divide the number of milligrams of the substance per litre of air by the molecular weight of the substance and then to multiply by 0.0224, to find the number of cubic centimetres of the gas in question per litre of air. One-tenth of the number of cubic centimetres represents the percentage; a thousand times the number of cubic centimetres per litre gives the parts per million.

It is also important to distinguish between gauge pressure and absolute pressure, the first only generally indicating the differential pressure and marking the difference between two absolute pressures.

The volume occupied by any mass of gas at a constant temperature is determined by the pressure exerted upon it. The change in volume is proportional to the change in absolute pressure, not gauge pressure. The volumes $V$ and $V'$ occupied by the same mass of gas at two pressures $P$ and $P'$ will therefore vary in the ratio:

$$\frac{V}{V'} = \frac{P}{P'}$$

That is, the pressure increases as the space occupied decreases and vice versa.

The pressure exerted by a mixture of gases in a collapsible container is equal to the pressure exerted upon it and is the sum of all the pressures of the component gases, when there is no chemical reaction. Each gas acts separately, according to the principle above stated, and the pressure exerted by each is known as its "partial pressure".

In physiology it is partial pressure which is of critical importance; thus, for example, a man can only live in an atmosphere in which there is a certain partial pressure of oxygen, below which there would be danger of asphyxia. This partial pressure varies with the gauge pressure and is expressed, for example, by 160 mm. at 760 and 151 at 750, etc. It must not, however, be forgotten that the well-being of a man does not so much depend on the constancy of the partial pressure. Thus, an atmosphere containing 5 per cent. oxygen at a pressure of 4 atmospheres (the partial pressure of oxygen will then be nearly normal, or 152 mm.) will maintain a man perfectly in respect to oxygen.

Raising of the temperature increases the volume of gases. The coefficient of expansion is the same for all gases, and for each degree of temperature the increase is $\frac{273}{T}$ of the volume at 0°C.

The general formula of the relative volumes is:

$$\frac{V}{V'} = \frac{273 + T}{273 + T'}$$

in which $V$ and $T$ are the initial volume and temperature and $V'$ and $T'$ the final conditions.
In all calculations relating to gas analysis, percentage readings are ordinarily made upon the basis of dry gas. To obtain accurate results, it is therefore essential to take into account the presence of a more or less extensive quantity of water vapour. When the gaseous mixture is saturated with the water vapour at a certain temperature, the correction for vapour pressure is wholly a function of the temperature and is entirely independent of the barometric pressure. In physiological work it is seldom necessary to consider partial saturation since gases inhaled with water vapour at the temperature of the body.

For comparison of gas volumes it is necessary that they be referred to standard conditions of temperature, pressure and moisture, that is, as they would be at 0° C., 760 mm. pressure and dry. For this conversion the following formula is used:

\[ V = \frac{(B - W) \times 973}{760 \times (273 + T)} \]

where \( V \) is the volume of (dry) gas at 0° C. and 760 mm., \( V' \) the volume observed, \( B \) the prevailing barometric pressure, \( W \) the partial pressure of water vapour, and \( T \) the observed temperature.

As regards the solubility of gases and fluids, it must be remembered that the amount of each gas that is dissolved in a fluid at any given temperature is directly proportional to the partial pressure of that gas acting upon the fluid, and is totally independent of all other pressure; that means that the weight of the same gas in solution is proportional to the pressure (Henry’s law). When several gases are in solution in the same liquid, each is subject to the same absorption as if it were the only gas present, each gas being brought to its particular pressure after absorption (Dalton’s law). Gases inhaled and absorbed by the blood obey this law.

A gas in contact with a fluid dissolves until the partial pressure of the gas in solution equals the partial pressure of the gas which remains undissolved. The quantity of gas necessary to attain this equilibrium varies with the nature of the fluid and the temperature. Although it is a general rule that with the rise in temperature less gas must be dissolved to produce any given pressure, the influence upon the amount dissolved which is exerted by temperature is subject to no simple rule, but is specific for each gas and each liquid.

It is therefore necessary to determine experimentally the solubility of each gas and each fluid at various temperatures. This value is known as the coefficient of solubility for the particular condition.

The solubility of gases in fluids may be expressed in terms of the weight of gas in solution in unit volume of the fluid, at given temperature and normal atmospheric pressure. The solubility of gases in fluids can be expressed in yet another manner by the “coefficient of distribution”. By this term is meant the relative weight of gas in equal volume of the gas mixture and of the fluid which are in gaseous equilibrium. In expressing the ratio of distribution, it is customary to take the concentration of the gas phase as the unit. Thus, in a system in which each litre of air contains 3 mg. of a given substance and a fluid in equilibrium with it contains 1 mg. in 3:12, and the coefficient of distribution would be expressed thus, 1:4 or merely as 4.

A difference exists between gases and fumes characterised by the fact that the latter exist not only in a gaseous state but also in the form of liquid at common temperature and pressure. Fumes obey the same laws as gases provided that none of the substance is present in liquid form, and that there is no passage from the gaseous phase to the liquid; on the other hand, the more dilute the mixture of fumes in air, the more nearly do they conform to the gas laws. Fumes cease to behave as a gas and tend to condense into the liquid form whenever the weight per volume of air, or the partial pressure of fumes measured at the existing temperature and barometric pressure, equals the maximum weight of partial pressure of the fumes, which can be developed by volatilisation in a closed vessel at the given temperature.

**Absorption and Elimination**

Noxious gases and fumes, other than irritants and simple asphyxiants, exert their action only after absorption into the blood. The intensity of the action, and in some cases even its character, are determined by the concentration in the blood, and the duration of its stay, and not merely by the inherent toxicity of the substance.

Gases and fumes absorbed by the blood are of two classes: reactive and non-reactive. The former are altered within the body and are eliminated in forms other than those in which they were absorbed. The toxicological action
may be due either to the substance in its original form or to the product of its reaction. Thus, ethyl alcohol is an example of a reactive vapour which exerts its action before its destruction has taken place, whilst aniline exerts its main action through the products arising from its reaction in the body. Non-reactive substances are not altered to any appreciable extent and are eliminated in the same form in which they are absorbed. An example of this kind is constituted by the aliphatic hydrocarbons. The absorption of non-reactive gases and fumes varies in accordance with their degree of solubility. The solubility of a gas in blood is only slightly less than its solubility in water. The capacity of the various tissues to dissolve gases varies in its turn: very low in bone and often very high in fatty tissues and those which are rich in lipoids. For gases and fumes the physiological properties of which have been studied, it may be said that the average solubility in the tissues of the body is in conformity with the solubility in the blood.

A factor which influences the absorption of gases and fumes is the concentration in the air breathed. To ascertain the physiological value of this concentration, the concentration in the surrounding atmosphere must be corrected by considering it when warmed to body temperature and saturated with moisture.

The pulmonary ventilation in its turn influences the absorption of gases and fumes. The latter depends upon the volume of air breathed and the amount of gas thus brought in contact with the blood. Finally, the circulation plays a part in the absorption of gases and fumes of relatively low solubility, the quantity of toxic substances absorbed being in direct ratio to the flow of the blood. At the commencement of inhalation gases and fumes taken up by the blood in simple solution are carried by the arterial stream to the capillaries, where they diffuse into the tissues. Between the latter and the blood nearly complete equilibrium is almost instantaneously attained and the venous blood possesses as a result of this equilibrium a concentration practically identical with that of the tissues; it then returns to the lungs for a fresh charge of the gas and hence the concentration constantly rises in the tissues. In virtue, however, of the equilibrium above referred to, the quantity of gas brought to the lungs by the venous blood augments at the same rate. The limit approached is a state of saturation at which the body will contain an amount of gas or fume equal to the product of three factors: the weight of the body multiplied by the concentration of the gas or vapour in the air in the lungs and by its coefficient of solubility at body temperature. Expressed graphically, this tendency gives a curve approaching the logarithmic.

As regards the absorption of reactive gases and fumes, it is in general the same as that of non-reactive gases and fumes, but with this difference: the reaction and consequent destruction undergone prevent the attainment of equilibrium between the blood and the tissues as in the case of non-reactive gases and fumes: thus, the quantity of gas carried to the lungs is inferior. The course of absorption is influenced by the rate of alteration of the gas or fume within the body, which varies for each substance.

The elimination of non-reactive gases is effected almost entirely by the lungs. Elimination by the urine and other secretions is of little importance, and the urine and other secretions carry away relatively small amounts.

The concentration of the gases dissolved in the urine corresponds to that which exists in the blood flowing through the kidney at the moment at which the urine is secreted. When elimination commences and part of the air in the lungs is replaced by fresh air, a part of the gas is carried away in the expired air, and the concentration of the gas in the arterial blood is reduced below that in the venous blood. The elimination of reactive substances is likewise influenced by their alteration within the body. The solubility of the gases and fumes in the various tissues does not only depend on the specific coefficient of each of these tissues, but also on the blood supply. Thus, despite a high solubility for a given gas, a tissue with a slow blood flow approaches saturation much more slowly than another tissue with a comparatively low solubility coefficient for the gas and a large blood flow. Tissues of small circulation and slow saturation influence saturation in the venous blood, and consequently also in the lungs and arterial blood.

Volatile substances may be absorbed through channels other than the respiratory passages, as, for example, in the case of ingestion of alcohol, administration of ether by way of the colon, and the absorption of aniline, tetra-ethyl lead, etc., by way of the skin. Under these circumstances, the volatile substances enter the venous blood, and it is the volume of breath-
ing and the rate of the blood flow which then determine the distribution of the substance between the air to be expired and the arterial blood to be distributed to the tissues of the body. The mechanism is thus regulated as in the case of elimination of gases and fumes absorbed by the respiratory tract.

It is not necessary to give here the classification of toxic gases, such a list being possessed of a rather theoretic interest. For details of interest in practice, reference is made to the various articles dealing with these gases. Thus, for example, for the group asphyxiant gases, see the articles "Acetylene", "Ethylene", "Explosives", "Cyanogen and Cyanides", "Carbon Monoxide", etc.; for the irritant gases, see the articles "Hydrochloric Acid", "Sulphuric Acid", "Fluorine and Hydrofluoric Acid", "Formaldehyde", "Sulphur Dioxide", "Chlorine", "Bromine", "Acrolein", "Nitrous Fumes", "Phosgen", etc.; for gases with an anaesthetic action, see the articles dealing with aliphatic hydrocarbons and the halogen compounds, the alcohols, etc.

There shall only be quoted here in the tables which follow the most characteristic data relative to the most important toxic products dealt with in this publication.

An opportunity has already occurred for describing the technique followed in taking samples of air for analysis (see article "Air Testing in Workshops"), as well as certain types of lamps used for detecting the presence of gas in mines and, in particular, firedamp (see article "Mines, Hygiene in"). Without going into further details to be found in treatises on toxicological chemistry, it suffices here to recall that a new apparatus for recording automatic estimation of combustible fumes (benzine, ether, etc.) is based on the varying viscosity and density of the different gases and fumes. This apparatus may be installed in a workroom in which inflammable fumes are liberated, the air serving for comparison being naturally drawn from outside (Dommer).

### TABLE I. — VALUES EXPRESSED IN VOLUME PER 1,000 OR IN MILLIGRAMS PER LITRE (ACCORDING TO BUNGE)

<table>
<thead>
<tr>
<th>Substances</th>
<th>Sudden death</th>
<th>Serious injury in 30 to 60 minutes</th>
<th>Without serious injury in 30 to 60 minutes</th>
<th>Slight symptoms after several hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrochloric acid (gas)</td>
<td></td>
<td>1.5-2°/1</td>
<td>0.05-1°/1</td>
<td>0.01°/1</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td></td>
<td>0.4-0.5°/1</td>
<td>0.03°/1</td>
<td>0.02-0.03°/1</td>
</tr>
<tr>
<td>Prussic acid</td>
<td>Appr. 0.2°/1</td>
<td>0.12-0.15°/1</td>
<td>0.06-0.06°/1</td>
<td>0.02-0.04°/1</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>30°/1</td>
<td>50-80°/1</td>
<td>40-60°/1</td>
<td>20-30°/1</td>
</tr>
<tr>
<td>Ammonia</td>
<td></td>
<td>2.5-4°/1</td>
<td>0.3°/1</td>
<td>0.1°/1</td>
</tr>
<tr>
<td>Chlorine and bromine</td>
<td></td>
<td>0.04-0.06°/1</td>
<td>0.00°/1</td>
<td>0.005-0.001°/1</td>
</tr>
<tr>
<td>Iodine</td>
<td></td>
<td>0.03°/1</td>
<td>0.001°/1</td>
<td>0.005-0.001°/1</td>
</tr>
<tr>
<td>Phosphoretted hydrogen</td>
<td></td>
<td>0.4-0.6°/1</td>
<td>0.1-0.2°/1</td>
<td>0.1-0.15°/1</td>
</tr>
<tr>
<td>Sulphuretted hydrogen</td>
<td></td>
<td>0.5-0.7°/1</td>
<td>0.2-0.3°/1</td>
<td>5-10 mg.</td>
</tr>
<tr>
<td>Petrol benzine</td>
<td></td>
<td>15-25 mg.</td>
<td>10-15 mg.</td>
<td>5-10 mg.</td>
</tr>
<tr>
<td>Benzene</td>
<td></td>
<td>10-12 mg.</td>
<td>70 mg.</td>
<td>5-10 mg.</td>
</tr>
<tr>
<td>Carbon disulphide</td>
<td></td>
<td>150-200 mg.</td>
<td>25-50 mg.</td>
<td>5-10 mg.</td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>300-400 mg.</td>
<td>Approx. 25-40 mg.</td>
<td>25-50 mg.</td>
<td>5-10 mg.</td>
</tr>
<tr>
<td>Chloroform</td>
<td>300-400 mg.</td>
<td>50-80 mg.</td>
<td>25-50 mg.</td>
<td>5-10 mg.</td>
</tr>
<tr>
<td>Aniline and toluidine</td>
<td></td>
<td>0.4-0.6 mg.</td>
<td>1.0 mg.</td>
<td>0.1-0.25 mg.</td>
</tr>
<tr>
<td>Nitro-benzene</td>
<td></td>
<td>1-1.5 mg.</td>
<td>0.2-0.4 mg.</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE II. — CARBON MONOXIDE (ACCORDING TO HARTRIDGE)

<table>
<thead>
<tr>
<th>Percentage of CO in air breathed</th>
<th>Time at the end of which symptoms occur</th>
<th>Percentage of CO in air breathed</th>
<th>In air breathed</th>
<th>In the haemoglobin after 30 minutes' respiration</th>
<th>Estimated in saturated haemoglobin</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01</td>
<td>Light</td>
<td>Serious</td>
<td>0.06</td>
<td>15.0</td>
<td>66</td>
</tr>
<tr>
<td>0.02</td>
<td>Light</td>
<td>Serious</td>
<td>0.135</td>
<td>20.5</td>
<td>66</td>
</tr>
<tr>
<td>0.03</td>
<td>Light</td>
<td>Serious</td>
<td>0.15</td>
<td>25.5</td>
<td>72</td>
</tr>
<tr>
<td>0.04</td>
<td>Light</td>
<td>Serious</td>
<td>0.18</td>
<td>29.5</td>
<td>72</td>
</tr>
<tr>
<td>0.05</td>
<td>Light</td>
<td>Serious</td>
<td>0.30</td>
<td>36.6</td>
<td>81</td>
</tr>
<tr>
<td>0.06</td>
<td>Light</td>
<td>Serious</td>
<td>0.60</td>
<td>53.0</td>
<td>90</td>
</tr>
<tr>
<td>0.10</td>
<td>Light</td>
<td>Serious</td>
<td>0.60</td>
<td>53.0</td>
<td>90</td>
</tr>
<tr>
<td>0.15</td>
<td>Light</td>
<td>Serious</td>
<td>0.60</td>
<td>53.0</td>
<td>90</td>
</tr>
</tbody>
</table>
**TABLE III. — INJURIES PRODUCED ON CATS BY TOXIC GASES** *(ACCORDING TO K. B. LEHMANN AND HIS PUPILS)*

*Doses Administered Expressed in Milligrams per Litre*

<table>
<thead>
<tr>
<th>Substances</th>
<th>Rapidly fatal or causing very serious injury</th>
<th>Serious injuries up to an immediate fatal issue or retarded fatal issue: 30 to 60 minutes' exposure</th>
<th>Without serious injuries immediately or later: 30 to 60 minutes' exposure</th>
<th>Without appreciable injuries (without acclimatization): 6 hours' exposure</th>
<th>According to Hess and Zangger</th>
<th>Grave injuries in 30 to 60 minutes</th>
<th>Very slight injuries after several hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitric or nitrous acid</td>
<td>ca. 8.0 or less</td>
<td>0.5-1.0</td>
<td>0.2-0.4</td>
<td>0.6-0.65</td>
<td>0.03-0.05</td>
<td>0.60-0.65</td>
<td>—</td>
</tr>
<tr>
<td>Hydrochloric acid</td>
<td>ca. 7</td>
<td>1-2</td>
<td>0.1-0.4</td>
<td>0.4-0.45</td>
<td>0.4-0.5</td>
<td>0.02-0.05</td>
<td>0.02-0.03</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>3-5</td>
<td>1.4-1.7</td>
<td>0.5-0.6</td>
<td>0.6-0.60</td>
<td>0.5-0.5</td>
<td>0.5-0.5</td>
<td>0.02-0.03</td>
</tr>
<tr>
<td>Ammonia</td>
<td>ca. 5-10</td>
<td>2-4</td>
<td>1.0</td>
<td>0.3</td>
<td>2.5-4.5</td>
<td>0.04-0.06</td>
<td>0.001</td>
</tr>
<tr>
<td>Chloride</td>
<td>ca. 2.5</td>
<td>0.1-0.5</td>
<td>0.01</td>
<td>0.003-0.005</td>
<td>0.04-0.06</td>
<td>0.04-0.06</td>
<td>0.001</td>
</tr>
<tr>
<td>Bromine</td>
<td>3.5</td>
<td>0.29-0.33</td>
<td>0.022</td>
<td>0.007-0.014</td>
<td>0.04-0.08</td>
<td>0.04-0.08</td>
<td>0.01</td>
</tr>
<tr>
<td>Sulphuretted hydrogen</td>
<td>1.8-3.6</td>
<td>0.7-1.2</td>
<td>0.6-0.6</td>
<td>0.12-0.18</td>
<td>0.5-0.7</td>
<td>0.1-0.15</td>
<td>0.01</td>
</tr>
<tr>
<td>Phosphuretted hydrogen</td>
<td>0.6 or less</td>
<td>Less than 0.01</td>
<td>0.01</td>
<td>Less than 0.001</td>
<td>0.4-0.7</td>
<td>0.01 (again fatal in 6 hours)</td>
<td>—</td>
</tr>
<tr>
<td>Arseneuretted hydrogen</td>
<td>5</td>
<td>0.05</td>
<td>0.02</td>
<td>Less than 0.03</td>
<td>0.02-0.03</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>—</td>
<td>0.2</td>
<td>0.2</td>
<td>2-3</td>
<td>—</td>
<td>0.2</td>
<td>—</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>150-200</td>
<td>40-120</td>
<td>60-70</td>
<td>50-80</td>
<td>30-45</td>
<td>20-30</td>
<td>—</td>
</tr>
<tr>
<td>Tetra-oxyde of osmium</td>
<td>—</td>
<td>0.03</td>
<td>0.001</td>
<td>0.0000000</td>
<td>0.02-0.04</td>
<td>0.02-0.04</td>
<td>—</td>
</tr>
<tr>
<td>Frusnic acid</td>
<td>0.2-0.3</td>
<td>0.12-0.15</td>
<td>0.06-0.06</td>
<td>0.03 (0.004)</td>
<td>0.03-0.04</td>
<td>0.12-0.15</td>
<td>—</td>
</tr>
<tr>
<td>Aniline</td>
<td>2 (approx.)</td>
<td>0.6</td>
<td>0.2-3</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Nitro-benzene</td>
<td>—</td>
<td>0.3</td>
<td>0.3 (approx.)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Benze chloride</td>
<td>1.2 (approx.)</td>
<td>0.1-0.5</td>
<td>0.00-0.00-0.01</td>
<td>0.004</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Trichloride of phosphorus</td>
<td>0.3 or less</td>
<td>0.1-0.02</td>
<td>0.04-0.05</td>
<td>0.004</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>2-4</td>
<td>ca. 0.5</td>
<td>Less than 0.1</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>10-20</td>
<td>ca. 1.0</td>
<td>0.5</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Benzealdehyde</td>
<td>—</td>
<td>0.5</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Acroleine</td>
<td>—</td>
<td>0.2 (approx.)</td>
<td>0.02 (approx.)</td>
<td>0.01</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Amyl ecetate</td>
<td>—</td>
<td>20.0 (approx.)</td>
<td>5.0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Phosgen</td>
<td>2.5</td>
<td>0.36</td>
<td>—</td>
<td>0.05</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Turpentine</td>
<td>10</td>
<td>4-6</td>
<td>2-3</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

1 The figures in this table are only given as an indication, especially the figures in the first column.
2 Without injury after a month of exposure with a dose of 0.1 (according to Ronzani).
3 Ditto, with a dose of 0.003.

**TABLE IV. — NARCOTIC ACTION OF CERTAIN TOXIC GASES AND FUMES ON CATS** *(ACCORDING TO K. B. LEHMANN)*

*Doses Expressed in Milligrams per Litre*

<table>
<thead>
<tr>
<th>Substances</th>
<th>Unconscious after 5-10 minutes</th>
<th>Unconscious or a prey to cramp after 30-60 minutes</th>
<th>Without injury after 30-60 minutes</th>
<th>Without appreciable injury after 6 hours</th>
<th>According to Hess and Zangger</th>
<th>Serious injury after 30-60 minutes</th>
<th>Slight injuries after several hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light benzine</td>
<td>100</td>
<td>70-90</td>
<td>10-30</td>
<td>10</td>
<td>25-10</td>
<td>—</td>
<td>5-10</td>
</tr>
<tr>
<td>Commercial benzo</td>
<td>50</td>
<td>20-30</td>
<td>10-15</td>
<td>5-10</td>
<td>10-15</td>
<td>—</td>
<td>5-10</td>
</tr>
<tr>
<td>Chloroform</td>
<td>80-120</td>
<td>60-80</td>
<td>10-15</td>
<td>5-10</td>
<td>150-200</td>
<td>—</td>
<td>10</td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>150-200</td>
<td>60-80</td>
<td>20</td>
<td>10-15</td>
<td>150-200</td>
<td>—</td>
<td>10</td>
</tr>
<tr>
<td>Tetrachlorathine</td>
<td>30-60</td>
<td>10 (approx.)</td>
<td>5</td>
<td>10</td>
<td>10-12</td>
<td>—</td>
<td>1-2</td>
</tr>
<tr>
<td>Carbon disulphide</td>
<td>10</td>
<td>7-10</td>
<td>3.5</td>
<td>1.5</td>
<td>10-12</td>
<td>—</td>
<td>1-2</td>
</tr>
</tbody>
</table>

Another apparatus, that suggested in 1927 by Rhode, for the analysis of gas measures on the one hand carbon dioxide, and on the other carbon monoxide, hydrocarbons and hydrogen. It is useful for the analysis of gases present in smoke.
for measuring gases in weak proportion. Varied combinations of the Hempel and Orsat apparatus have enabled them to create apparatus for measuring one or two gaseous elements of the mixture.

**INDUSTRIAL GASES**

In the following there shall be dealt with in order: gases captured or specially prepared with a view to their action as combustibles; gases possessing the same usage, but given off as by-products in certain operations; gases recuperated with a different object from that indicated above; harmful gases liberated in important quantities in certain industrial operations; and finally, gases escaping into the atmosphere from high factory chimneys.

These various aspects are treated in a fairly summary manner and merely by way of recalling the more detailed information which the reader will find in the various special articles of the Encyclopædia.

**Gases Captured, or Prepared Specially with a View to their Action as Combustibles**

*A. — Gas from Natural Combustion Agents*

It is known that combustible gases escaping from the earth have long been utilised and employed for different purposes (heating, lighting). For thousands of years back, for instance, they have been employed in China for evaporating salt and for centuries, for instance, by marsh land or at places where any organic substances exist in a state of putrefaction under water, etc. The gas in question is always found in coal mines, where it is formed by slow decomposition and remains occluded under strong pressure, together with carbon dioxide and nitrogen existing in the coal itself.

Methane is easily inflammable and burns with a very slightly luminous flame. Mixed with oxygen, it forms a detonating mixture; mixed with air, it forms "firedamp".

There may be recalled in passing the interesting laboratory experiences effected in 1929 in the United States with a view to industrial application and concerned with the reaction between chlorine and methane, with a view to obtaining carbon tetrachloride, chloroform and methyl chloride.

**B. — Town Gas**

There is meant by town gas, gas exclusively derived by the distillation of coal without the addition of water gas or other gases.

The installation and working of gas factories being described in the article "Gas-Works", mention will here be restricted to indicating that the average composition of coal gas by distillation at high temperature (1,000 to 1,100° C.) is as follows, expressed in percentages:

<table>
<thead>
<tr>
<th>Component</th>
<th>Per cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>30 to 40</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>45 to 50</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>7 to 13</td>
</tr>
<tr>
<td>Higher carbides</td>
<td>3 to 4</td>
</tr>
<tr>
<td>Nitrogen and carbon dioxide</td>
<td>2 to 3</td>
</tr>
</tbody>
</table>

It is known that physical refining of town gas eliminates the heavy carbides, the salts of ammonia and the tars, whilst chemical refining removes the free ammonia, the carbon dioxide and the sulphuretted hydrogen. It is also known that ordinary manufacture of town gas necessitates the use of special coals rich in volatile substances.

During the last few years considerable effort has been made in the sphere of industrial technique relating to the carbonisation of coal at a low temperature. This process consists in heating solid combustibles in a closed receptacle from 500 to 600° C. in order to extract volatile combustibles capable of condensation or otherwise at an ordinary temperature, whilst leaving a solid residue which is still at least partially fit for utilisation. It seems that this new method is not yet economically profitable, except with coals of medium value very rich in

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1 Original report by Dr. D. Gliert (Brussels) (up to Statistics on p. 844).
cinders, or in countries where liquid combustibles are extremely expensive.

C. — Oil Gas

This gas is obtained by causing middle petrol oils, schist oils and resin oils to fall into retorts brought to red heat. It consists of methane, ethylene, benzole and acetylene. It burns with a highly luminous and calorific flame. Compressed to ten atmospheres in special reservoirs, it is used for lighting railway compartments. This gas, then, known under the name of Pintsch gas, may be mixed with acetylene (25 per cent.).

Blau gas is not, so far, well known. It is a gaseous carburettant prepared to 1q07 by Fritz Blau (whence its name, and not because it is blue), and is a mixture obtained by heating mineral oils to a temperature of between 500° and 600° C., that is to say, a kind of oil gas. According to other experts, this gas is only ethylene.

D. — Producer Gas

(a) Air gas. — There is designated under this name the product of an incomplete combustion of a solid combustible: wood, peat, lignite, coal, coke, etc. The composition of air gas depends on the nature of the combustible used and the temperature at which the reaction is effected (cold or hot generator process); this gas, however, contains principally carbon monoxide and nitrogen. Below are given certain results of the analyses1 of air gas:

<table>
<thead>
<tr>
<th>Product from wood charcoal</th>
<th>Product from coke</th>
<th>Product from crude combustible</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In volume</td>
<td>In weight</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>33.3</td>
<td>34.1</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>63.4</td>
<td>64.9</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>0.5</td>
<td>0.8</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>2.8</td>
<td>0.2</td>
</tr>
<tr>
<td>Hydrocarbides</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

In the manufacture of air gas there must be taken into account the quantity of water introduced into the apparatus, either in consequence of the use of crude combustibles or in the state of steam as well as the air destined for combustion. The decomposition of the water into its two elements is the more marked the hotter the generator process is.

(b) Water gas (blue gas). — Water gas, or poor gas, is only the mixture of gas obtained by the decomposition of water under the influence of incandescent carbon. Theoretically, the decomposition takes place according to the following formula:

\[ H_2O + C = H_2 + CO \]

or the same volume of hydrogen and carbon monoxide with a weight of 6.7 of hydrogen and 93.3 of carbon monoxide. This theoretical reaction, however, is only carried into practice at a very high temperature. Further, the combustion agents used for the manufacture of water gas (coke, anthracite and other combustibles poor in volatile substances) react also on the composition of the gas, and on an

1 Hartridge gives the following composition for certain industrial gases:

<table>
<thead>
<tr>
<th>Industrial gases</th>
<th>Percentage in volume</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( H_2 )</td>
</tr>
<tr>
<td>Water gas or blue gas</td>
<td>52.0</td>
</tr>
<tr>
<td>Carburetted water gas</td>
<td>35.0</td>
</tr>
<tr>
<td>Mond gas</td>
<td>97.5</td>
</tr>
<tr>
<td>Dowson gas</td>
<td>30.0</td>
</tr>
<tr>
<td>Producer gas</td>
<td>16.0</td>
</tr>
<tr>
<td>Ditto</td>
<td>16.0</td>
</tr>
<tr>
<td>Blast furnace gas</td>
<td>3.0</td>
</tr>
<tr>
<td>Coke furnace gas</td>
<td>53.0</td>
</tr>
</tbody>
</table>
average the composition is shown to be somewhat as follows:

<table>
<thead>
<tr>
<th></th>
<th>In volume</th>
<th>In weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>48.00</td>
<td>5.9</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>43.00</td>
<td>75.4</td>
</tr>
<tr>
<td>Methane</td>
<td>1.00</td>
<td>1.0</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>3.50</td>
<td>9.9</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>4.00</td>
<td>7.8</td>
</tr>
</tbody>
</table>

In large establishments the same apparatus serves successively for the production of air gas and water gas. In the manufacture of air gas, there is created in the heated chamber an extremely high temperature (white heat) which the introduction of steam causes to fall rapidly.

Water gas serves as town gas when its calorific power is increased by means of light petrol oils. It furnishes the hydrogen necessary to direct liquefaction of coals in accordance with the Bergius process, to the production of methylnol obtained in treating a mixture of hydrogen and carbon monoxide by a catalyster, and to the production of synthol, a compound of alcohols and cetones, etc.

(c) Poor gas (Dowson gas). — “Poor” in lighting power, it may be considered as a mixture of water gas and air gas. It is prepared by injecting into coke or anthracite brought to red heat (1,000 to 1,200° C.) super-heated steam at the same time as air in proportions exactly calculated to serve the right thermic equilibrium.

Apparatus exists, enabling the poor gas to be enriched by the production of hydrocarbides resulting from the volatilisation of petrol, which is then drawn off by the gaseous current feeding the combustion temperature. It is used principally for heating metallurgical furnaces, for the production of motor power in the case of gas motors, etc.

A similar gas is Mond gas, which is obtained by the gasification of refuse of coal, bituminous schists, lignite, peat, in special generators which permit also of the gasification of the tar formed in course of the dry distillation to which these products are at the same time subjected. More than 70 per cent, of the nitrogen contained in the combustible is transformed into ammonia, which is recuperated in the form of ammonium sulphate by washing the gas in absorption towers (by means of sulphuric acid).

Gas Used as a Combustible and Derived from By-Products in Certain Processes

A. — Gas from Coke Ovens

The manufacture of coke does not differ essentially from the manufacture of town gas, since in both cases it is a question of tar distillation. The quality of the latter is, however, different in the two cases, as is likewise the aim in view. In the manufacture of coke, recovery of the volatile products of distillation becomes a secondary consideration, or is totally overlooked. In the latter case, which for long was the rule, the gases are liberated freely into the atmosphere and the carbon monoxide is generally burnt at its exit. In the case of recovery, the gases are utilised for heating the apparatus. The disadvantages connected with the gas are therefore similar under both circumstances, whether it be a question of town gas or gas from coke ovens, though in the first case their recovery is much better assured than in the second.

By-products of the transformation of coal into metallurgical coke contain on an average per ton, besides ammonia, benzole (14 kg.) and tar (30 kg.):

- 20 cub. m. or 35.5 kg. of carbon monoxide.
- 191 cub. m. or 12.05 kg. of hydrogen.
- 192 cub. m. or 86.5 kg. of methane.
- 13 cub. m. or 10.3 kg. of ethylene carbides.

B. — Gas from Blast Furnaces

In modern siderurgy, gases from blast furnaces possess very considerable economic importance. They are, in fact, intensely rich from a calorific point of view, and efforts are made to profit by this fact as far as possible for industrial purposes. Their composition at the furnace mouth varies quantitatively and sometimes qualitatively with different circumstances: running of the furnace, nature of the ores treated or the flux added, etc. However, it may be stated that the average composition of these gases approaches, as far as the principal elements are concerned, the following:

<table>
<thead>
<tr>
<th></th>
<th>In volume</th>
<th>In weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>60.0</td>
<td>58.0</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>24.0</td>
<td>24.0</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>12.0</td>
<td>17.0</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>2.0</td>
<td>0.2</td>
</tr>
<tr>
<td>Hydrogen carbides</td>
<td>2.0</td>
<td>0.8</td>
</tr>
</tbody>
</table>
These gases are accompanied by dusts in the proportion of 1 to 5 grm. per cub. m., and steam in the proportion of 8 to 15 per cent. in volume. Freed from these two impurities, they serve to produce the heat necessary for boilers, and to heat the air for recuperators.

Independently of the gases mentioned above, there exist in blast furnaces, in relatively large quantities, very varied toxic gases, especially cyanogen and sulphuretted products. The cyanogen results from the combination of nitrogen with the potassium or sodium contained in the mixing bed. There are thus formed, in course of the process, alkaline cyanides, which, after volatilisation, are carried away in the gaseous current. L. Bell, in a coke blast furnace 24 m. in height, found 15 grm. of cyanogen, 29 grm. of potassium and sodium per cub. m. of the gas recovered at 2.50 m. above the blast pipes. The sulphuretted products result from the sulphur insufficiently eliminated during the roasting of pyrites or contained in the cokes or fluxes. Finally, there is found besides in the gas from blast furnaces volatile substances varying with the nature of the charge of the mixing beds. These substances may contain arsenic, antimony, phosphorus, zinc, lead, etc.

**Gas Not Used as a Combustible but Recovered for Another Purpose**

A. — *Gas from Roasting*

Roasting is an operation by which various minerals are subjected to a fairly high temperature with a view to preparing them for further industrial treatment. Thus, for example, carbonated spathic iron is roasted with a view to its transformation into a more oxygenated iron with production of carbon dioxide and carbon monoxide. Most usually, however, roasting is effected with a view to eliminating from the raw materials used in metallurgy the sulphur which they contain. Yellow pyrites or white marcasite (FeS₂), magnetic pyrites (Fe₃S₄), copper pyrites (CuFeS₂), arsenical pyrites (Fe₃As₂), blende (ZnS), galena (PbS), are specially submitted to roasting. Under the influence of heat the sulphur contained in the above compounds passes into the state of sulphur dioxide, and may be used in the manufacture of sulphuric acid (see that article). It should be noted that frequently the liberation of these sulphurous products is accompanied by those gaseous products with basis of the toxic substances which have been already referred to: for example, the arsenic fumes given off pass into the state of arsenic acid, etc.

B. — *Hydrochloric Acid*

Hydrochloric acid (HCl) is a by-product in the manufacture of sulphate of sodium (see that article). Hydrochloric acid fumes given off from the furnaces where the reaction of sulphuric acid on sodium chloride is effected are extremely abundant, and as they have only a fairly limited value recuperation is frequently only partial, and is accompanied by insufficient ventilation of the furnaces. It is for this reason that a considerable part of the hydrochloric gas is discharged into the surrounding atmosphere amongst the workers, and is set free in the atmosphere to the detriment of vegetation within a radius which is at times very extensive. There should therefore be required a very well-controlled process of recovery in such factories, as well as complete or at least adequate neutralisation calculated to counteract the harmfulness of hydrochloric acid prior to its entry into the evacuating chimneys.

**Injurious Gases the Production of which is Connected with Various Industrial Processes**

The number of industrial processes in the course of which liberations of injurious fumes or gases are produced is very considerable, and it does not come within the scope of this article to mention these at length. The liberation of such gases is dealt with in the *Encyclopaedia* in each of the articles concerned with the industries with which they are connected. As an example, however, there may be quoted here certain of the more important gases liberated:

A. — *Gas from Furnaces for the Reduction of Zinc Ore*

There are given below the results of analyses effected by the Belgian Medical Factory Inspectorate. The samples of gas taken from the chimney con-

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Footnote: 1 For the technique followed in zinc factories, see article "Zinc."
phates depends on the nature of the ore manipulated. It is sometimes present in such abundance that it causes etching of the window panes within a very extensive radius. It is shown in the researches effected by Cristiani (Geneva) that fluorine may be extremely harmful to animals and man, otherwise even than by the direct irritation of the accessible mucous membranes which it causes. In the manufacture of superphosphates attempts are made to fix the fluorine by the following method; the gases after passing through two condensers are brought into contact with two columns where they are subjected to the action of steam which transforms the SiF₄ into gelatinous silica and into hydrofluosilic acid; thereafter the gases are directed under the hearth of the furnace, where they are subjected to combustion.

**Gas from Factory Chimneys**

Besides the dust particles, at times extremely abundant, with which factory chimneys contaminate the atmosphere, they give rise to further contamination by the emission of gas and fumes, the composition of which varies according to the type of manufacture of which they constitute the gaseous residue. Apart from the disagreeable and at times nauseous odours which they disseminate (e.g. manufacture of stearine candles), they contain of necessity considerable amounts of carbon dioxide and carbon monoxide.

The most commonly harmful gases, especially for vegetation, are, however, of a certainty sulphur dioxide, hydrochloric acid, and sulphur trioxide. The following are by way of information a few results of recent analyses:

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**Factory for the reduction of zinc ore.**

- The gases from the large factory chimney contained 0.828 grm. of sulphur trioxide and dioxide per cub. m.

**Chemical products factory (gelatine, sulphate of sodium, hydrochloric acid).**

- The chimney evacuated in twenty-four hours 189,369 cub. m. of smoke containing 74,508 kg. of sulphur dioxide and trioxide, or 0.353 grm. per cub. m.

The gas from this chimney contained in addition at the same time 90,139 kg. of hydrochloric acid in the form of fumes, or 0.476 grm. per cub. m.

**Manufacture of gelatine, sulphuric acid, hydrochloric acid, and sodium sulphate.** — The chimneys of this fac-
tory emitted 300,000 cub. m. of smoke in twenty-four hours. The smoke contained 2,000 kg. of sulphuric di- and tri-oxide, or 1.232 grm. per cub. m.; 192.700 kg. of hydrochloric acid in the form of fumes, or 0.270 grm. per twenty-four hours.

Metallurgical factory. — The chemical balance from the chimneys of this factory revealed a daily output of 11,102,400 cub. m. of smoke and combustion gases mixed. These gases contained 29,000 kg. of sulphur di- and tri-oxide.

A verification test by means of a Pitot tube gave a dilution of 1/180 per cent. by volume.

Copper and metal factory. — At the exit of the Gay-Lussac towers there was registered a loss of 188.084 kg. of sulphur di- and tri-oxide per twenty-four hours.

Brick factories. — A group of three brick factories provided the following analyses:

First brick factory: 400.665 kg. of sulphuric di- and tri-oxide per twenty-four; 7.712 kg. of hydrochloric acid in the form of fumes.

Second brick factory: 1,223.170 kg. of SO₂ + SO₃; 21.556 kg. of HCl in the form of fumes.

Third brick factory: 433.998 kg. of SO₂ + SO₃; 7.785 kg. of HCl in the form of fumes.

Statistics

It would hardly appear necessary to quote here again those statistics relative to poisoning by gases and fumes which are to be found in various articles of the Encyclopædia. It is however interesting to record statistics relative to cases of severe poisoning by gases and fumes furnished by the annual report of the Chief Medical Inspector of Factories of England and Wales:

Physiopathology

From the point of view of their physiopathological action, gases and fumes may be divided into irritant and asphyxiant gases, blistering and halogen gases. This classification permits division into groups giving rise to similar symptoms. Thus all the volatile gases and fumes from strong acids, or substances liberating halogen compounds (chlorine, bromine, phosgen, etc.) cause violent suffocation with fits of coughing and pulmonary oedema setting in ten to twelve hours after the accident. In the second stage local infections, and especially localised pulmonary necroses, are noted. On the other hand, substances which are simply irritant, such as the organic halogen products (chlorine-acetone, bromine-acetone, ethyl, chlorofomate, etc.), restrict their action to attacking the mucous membrane (conjunctiva, nose, pharynx and larynx) only, and rarely set up serious and lasting lesions. However, the fact must never be lost sight of that the clinical picture of the symptoms observed depends on the concentration of the toxic substance and the duration of its influence and the conditions of reduced resistance of the victim (fatigue, etc.). The chemical constitution of the toxic product only plays a role of secondary importance, with the result that very often local symptoms such as necroses can not be localised after of coughing and pulmonary oedema...
no longer be distinguished as resulting from specific products. A more rapid action on the nervous system is exercised chiefly by the liposoluble products, such as for instance the organic halogen compounds. In this case there are noted nausea, titubation, interference with consciousness, and depression.

Towards the beginning of the action of the various gases the symptoms observed are generally interpreted by yawning, a pricking or burning sensation or diffuse pains in the eyes, with for instance watering of the eyes and palpebral spasm. As regards the respiratory apparatus there is noted coughing and vomiting with arrested respiration. There then sets in hyperaemia, with nasal, lacrymal and salivary hypersecretion, and finally pulmonary oedema.

The most serious symptoms are the pulmonary symptoms. When poisoning attains a certain degree of gravity it produces desquamation of the pulmonary epithelium and oedema with fatal effect within the first twelve hours, but which may however be retarded for two or three days. Retarded causes of death are due generally to consequent pulmonary and pleural inflammations (Zangger).

**FIRST AID**

Rescue workers should be provided with respiratory apparatus. The victim should be immediately removed from the harmful area, great care being taken to transport him without subjecting him to effort. He should be undressed and put into a hot bath, since very often the gas clings to hair and clothing. Antidotes are not productive of good results unless administered during the first moments of poisoning. The harmful action progresses simultaneously with the alteration of the toxic gas, which fact renders useless the administration of antidotes which may in their turn prove harmful (e.g. use of ammonia in the case of poisoning by acid gases).

The action of the heart should be supervised and efforts made to prevent as far as possible the occurrence of pulmonary oedema; complete rest is necessary, whilst the patient should be spared every effort and every condition likely to render respiration difficult. He should be protected against chill, and a moderate amount of oxygen should be administered without unduly high pressure. It is preferable to make the patient breathe air into which oxygen is liberated at the rate of about 5 litres per minute near the face.

Artificial respiration is dangerous and should only be employed where the case in question is one of poisoning by narcotic fumes, carbon monoxide or cyanogen compounds. Ocular irritation may be treated by washing with a soda solution (0.5 per cent.). Similarly, gargling with a soda solution of 1/2 per cent. is recommended. Finally, where pain is present the inhalation of slightly anaesthetic fumes (essence of peppermint) may relieve the patient. When pulmonary oedema occurs bleeding should be effected, 300 to 500 cu. cm. of blood being withdrawn. An artificial serum can at the same time be injected subcutaneously and intravenously. In certain cases recourse is had to injections of the Ringer solution with a view to diminishing the permeability of the pulmonary capillaries. Finally, injections of glucose (10 to 20 per cent.) are also considered as even more effective than injections of kitchen salt.

Special efforts must be made to avoid the use of substances exerting a paralysing action on the respiratory system: heroin, morphine, codeine or scopolamine. Similarly, the use of vasodilating agents (nitro-glycerine) is to be avoided.

Recourse may be had to calming and general hypnotising drugs, such as those exerting cardio tonic action: camphor and its substitutes.

Finally, there must be taken into account the hypersensibility of certain individuals who have previously been exposed to poisoning, a hypersensibility which may last for weeks and even months (Zangger). (See also article "First Aid").

**HYGIENE**

In order to prevent the harmful effect of gases and fumes, three conditions are essential:

1. A knowledge of the physiopathological characteristics of the gas in its various concentrations, and the duration of this action;

2. The application of such knowledge with a view to preventing diffusion in the air to be breathed of the gas in toxic concentration;

3. The substitution where the above-mentioned means of prevention are not possible of special measures applied to the individual, who should be furnished with
special apparatus protecting him against inhalation of the gas.

In order to conform to the first condition it is absolutely essential to instruct those affected with regard to the harmful action of those gases and fumes to the influence of which they may eventually be exposed. For those substances the action of which is not yet sufficiently known physiological research should be instituted in order to determine the dangers involved by their use.

As regards the second condition, which comprises the prevention of atmospheric pollution, various methods have been recommended. One of these methods consists in making the air pass through an absorbent substance which catches the harmful agents. One of the most commonly used substances is wood charcoal which presents the advantage of yielding up, as a result of the compressing action of steam, the gases and fumes absorbed. Another process which it is possible to use in certain cases consists in mixing the polluted air with chlorine in small quantities. This gas destroys in the presence of steam a certain quantity of the harmful substances, such as sulphuretted hydrogen, etc.

Finally, in order to remove the evil at its origin, operations giving rise to injurious gases and fumes should be effected in airtight apparatus. This procedure offers the great advantage of restricting danger to the moment at which the said apparatus are opened. In order to prevent emission of gas at this moment, it suffices to create inside the apparatus a depression capable of causing aspiration of the outside air. In the absence of an installation of this kind, there are most commonly used exhaust hoods under which the operations producing toxic gases and fumes are effected. Numerous varieties of these types of hoods exist. They are generally made of sheet iron, except where it is a case of withdrawing acid products, in which case it is necessary to use material proof against attack by the products in question. Sometimes the hoods are provided with sliding panels which may be raised or lowered, thus effecting, to a certain extent, execution of the work in a closed receptacle.

When the processes take place above hearths which radiate heat, effective ventilation should be assured. In principle, the dimensions of the hood should be adapted to the work in progress, at the same time assuring adequate height and width. The draughts in the hoods may be either natural or artificial. The natural draught is favoured in its action by the presence inside the hoods of gas burners, or water or steam injectors acting as exhaust pumps. The artificial draught is effected by mechanical exhaust by connecting the hood to an exhaust pipe. This procedure makes it possible to construct hoods of reduced dimensions and thus to assure the capturing of fumes nearer to their point of origin. In certain cases the artificial draught may be combined with insufflation. Particular importance should be bestowed on the construction of these hoods and of the workrooms in which they are situated in order to avoid defective working due to the position of the hood or to the influence of the ventilation system of the workroom.

Evacuation pipes are mostly connected up to an exhaust system. The latter may be per descensum (downward draught) or per ascensum (upward draught), according to the nature of the gases and fumes.

In general, the gases and fumes absorbed are not, as in the case of smoke, directly emitted into the surrounding atmosphere by means of high chimneys. The gases may sometimes possess a market value, but, what is still more frequent, they may exercise a harmful action on the neighbourhood (population, vegetation).

It is necessary to emphasise the fact that the toxic particles, withdrawn into the chimneys by the hot gases from the factory, become disseminated in an impalpable cloud which very often penetrates into the workrooms with the outside air.

These dusts, in a very fine state of subdivision, are veritable quasi-colloidal suspensions, very stable aerosols, which penetrate with the inhaled air into the pulmonary alveoli.

The filtration of these clouds of smoke and gas is naturally very difficult and it appears that only electric precipitation is productive of good results.

In order to meet legislative requirements which demand neutralisation of toxic gases before their emission into the atmosphere, employers have recourse to several processes, in accordance with the nature of the gas or fumes, and in accordance also with the industrial processes followed in the factory.

In order to meet legislative requirements which demand neutralisation of toxic gases before their emission into the atmosphere, employers have recourse to several processes, in accordance with the nature of the gas or fumes, and in accordance also with the industrial processes followed in the factory.
apparatus of varying forms and dimensions, generally in absorption towers. The water or the fluids arrive in the upper part of these towers and fall in the form of rain or in powdered form, whilst the gases and fumes are aspirated or pushed in the opposite direction. Water dissolves a great number of fumes and gases and when it does not dissolve them its use involves a notable reduction in temperature favourable to the condensation of the fumes (ether, carbon bisulphide). Sometimes the condensation of the gases constitutes an essential part of manufacture (lead foundries, manufacture of metalloids, chemical products factories). The gases and fumes may also be led into closed chambers in order to act on products situated there and give rise to a special reaction (manufacture of chloride of lime, bleaching by sulphur dioxide, etc.).

Gases and fumes may again be neutralised by causing them to pass through substances capable of altering them (sulphate of silver, permanganate of potash for sulphur dioxide, etc.).

Gases and fumes not possessing any market value are burnt: elimination of malodorous gases (cesspools) or harmful gases (gas foundries). Combustion is effected in the hearths of steam-driven machinery or in other heat sources. This method can naturally only be applied to non-explosive gases. It must also be remembered that certain gases are used for heating purposes.

The purification of metallurgical gases is very important from the point of view of the cost price since it is a question of recovering dusts which are of interest from the standpoint of hygiene — these dusts carry toxic products into the atmosphere — or from the point of view of their further utilisation, since they can only be used if purification be carried to a very high pitch.

Modern industrial technique employs for this purpose several types of apparatus, known as washing apparatus, filtration apparatus, cooling apparatus, friction apparatus, expansion apparatus, or electrostatic apparatus.

Amongst the types of washing apparatus used especially in siderurgy the most commonly employed is the Theisen apparatus, the principle of which is that of churning of the water and gas by means of small paddles turning in a fixed trough. Technical progress has succeeded in obtaining a gas which contains less than 2 cg. of dust per cub. m. The dust separated in the form of mud is decanted, which demands the use of large vats occupying much space. The Neustadt system, however, provides a solution of the problem by the use of vats permitting of methodical and continuous decantation of the mud.

In metallurgy, as well as in sideryurgy, filtering apparatus utilising as filtering material wool, cotton and asbestos, etc., is used. Beth filters are very well known as well as the Halberg-Beth system of dry filtration.

Crude gases, cooled by passing them over a cooling machine (by radiation) after preliminary superficial purification, arrive in filtration apparatus consisting of a box divided into compartments, generally eleven in number, each of which contains a certain number of cylindrical bags in cotton felt, usually between twenty and thirty-five. These gases follow an ascending movement and after passing through the bags reach the compression pipe.

Electrostatic purification is none other than the Cottrell method, which became adopted industrially in 1906 and which is described in the article "Dust." This method is also applicable to the manufacture of acids for condensation of gas bubbles. It appears that the humidity and acidity rate of the surrounding atmosphere plays a certain part in the success of this method when given practical effect. It would seem to be on the point of entering into a new phase, since it appears that with periodical reversal of the gaseous current effected simultaneously with agitation of the wire, extremely interesting results are achieved, either in regard to the hourly quantity of the flow of gas or in regard to the degree of purification (2 cg. and perhaps 3 mg. per cub. m.)

Apart from exceptional gases such as arsine or phosphorettered hydrogen, there are others, such as ammonia, sulphuretted hydrogen, etc., which are generally present in industrial smoke. These gases, however, are generally present under such conditions that they appear to exercise only a slight influence on the health or at least it is particularly difficult to reveal this influence.

It is, however, necessary to direct attention to the quantities, at times enormous, of carbon monoxide contained in industrial smoke, the danger of which in regard to the health of men and of animals is very well known. It is therefore necessary to ascertain a means of recuperating and utilising to a greater extent the calo-
risic power of these last-mentioned products. The means employed with this in view vary from one industry to another and must, in consequence, be made the subject of particular description relative to each of the industries in which these gases are met with in any abundance. In general it is a case of smoke-devouring processes which transform the CO into CO₂.

As regards sulphur dioxide and sulphur trioxide, the problem often resides in the following alternative: either recovery, with a view to transformation into sulphuric acid, or dilution for vegetation; but there are rendered innocuous for the neighbourhood. The first process is economic, the second extravagant. There exists, however, a limit in the SO₂ and SO₃ content below which recovery is no longer economical, just as it is no longer economical when the total quantity of the smoke is insufficient. The problem which requires solution is that of reducing these limits. It should be noted that in certain special cases a good method of fixing sulphur dioxide is by the addition of lime to the combustion agent. This method, which is serviceable when it is a case of intimate mixture, has been rendered compulsory for certain brick works in Belgium.

As regards hydrochloric acid, it is more destructive in its effects than sulphur dioxide for human beings and for vegetation; but there is no other means of eliminating it than by complete condensation and neutralisation prior to rejection from the factory chimney.

In cases in which it is impossible to carry into practice means of purifying the atmosphere recourse must be had to the use of various apparatus and of respiratory masks (see articles "Breathing Apparatus" and "Industrial Hygiene: Workshops").

When, in spite of the measures taken, accidents occur, the victim should receive instant first aid followed by adequate treatment later. The rescue should be effected in conditions which do not involve risk for the rescue worker. The latter should be provided with a respiratory mask when it is a question of removing an asphyxiated worker from contaminated atmosphere (see article "First Aid").

J. S. Haldane (1926) discovered that circulation of the blood as well as respiration depends on the oxygen and carbon dioxide content of the blood in the sense that it is stimulated by an excess of carbon dioxide and a lack of oxygen.

If an excess of carbon dioxide be introduced it acts in the same way as a lack of oxygen and aids in stimulating circulation. As a result of this discovery, he made a study of an apparatus enabling large quantities of carbon dioxide to be developed in small volume, rendering the carbon dioxide method of great advantage as a remedy in cases of gas asphyxiation.

**Legislation**

Women are in general excluded from all work involving contact with toxic gases and fumes. In Argentina they are excluded from refining and distilling of petrol and hydrocarbons used for lighting and heating. In the United States (for example, in the States of Alabama, Arkansas, California, Connecticut, Kentucky, Maryland, New Jersey, Ohio, Oklahoma, Wisconsin) young persons under sixteen years of age are excluded from factories where toxic gases or fumes are liberated, from the manufacture of substances liberating toxic gases or fumes (New Jersey). Young persons under fifteen years of age are excluded from the manufacture of toxic gases (Delaware). Those under sixteen years of age are excluded from the distillation of petrol, automobile spirit, etc., as well as from stores for these, in France. Boys under sixteen years of age and women under twenty-one are excluded from compressed gas factories (carbon dioxide, oxygen, ammonia) in Spain. Boys under fifteen and women under twenty-one are excluded in Italy from compressed gases factories, etc.

In general, legislation with regard to gases and fumes is included under that devoted to the chemical industries (see articles "Chemical Trades", "Nitro and Amino Derivatives", "Explosives", etc.). Measures, however, have also been issued relative to compressed gases, liquid and dissolved gases, technique in regard to the production of which is at the present time extensively followed. Mention will here be restricted to the two most recent regulations: the Italian Regulations of 9 January 1927 and the Belgian Royal Order of 30 April 1927.

The Italian Regulations consider as "toxic gas" any toxic substance present in a gaseous state or requiring before utilisation passage into a gaseous phase or in the state of fumes which is used on account of its toxicity or for reasons inherent in the said toxicity; any toxic substance present in a gaseous state or requiring before utilisation to pass into the gaseous phase or into the state of fumes and which prior to its employment, for reasons Independent of its toxicity, is considered as endangering public safety and convenience.

The list of these substances comprises hydrocyanic acid (gaseous, compressed and
The Belgian Royal Order sets forth conditions to which the receptacles destined to contain liquefied, compressed or dissolved gases must conform. The gases in question at a pressure exceeding 1 kg. per square centimetre must be stored in receptacles made of forged or welded iron, forged or welded steel, or drawn steel formed of one piece. Where, however, the compressed gas is stored at a pressure not exceeding 23 kg. per square centimetre, receptacles in one piece "without welding" may only be used. The following gases: carbon oxychloride, methyl chloride, ethyl, sulphur dioxide, may be stored in copper receptacles.

There follow measures connected with the thickness of receptacles made of a single piece "without welding", receptacles welded by blow-pipe or by forge, the regular thermic treatment of receptacles after manufacture, the testing of the qualities of the metal and of the receptacles, bursting tests, etc.

Receptacles made of copper with a line of welding must be welded by tin. Other measures deal with the responsibilities of employers and proprietors of receptacles, the fitting of receptacles, receptacles for acetylene in solution, the protection of escape valves, the tests, the calibration and the interior capacity for holding water, filling of the receptacles, the indications with which receptacles must be fitted, the quality of oxygen and hydrogen gases, the periodicity of the tests, the certificates, etc.

Section 12 lays down that the top part of the receptacles should be covered to a height of 15 cm. with a wash of colour the hue of which should be the same for all receptacles containing the same gas. The colours allowed are red (hydrogen), green (nitrogen), bright yellow (carbon dioxide), blue (compressed air), light grey (oxygen), black (acetylene), black and white (chlorine), blue and white (ammonia) 1.

In regard to compensation for the injuries caused by gases and James, Japanese legislation provides compensation in the case of conjunctivitis due to irritant gases; British Columbia for dermatitis due to sulphur present in sulphur- etted gases; Missouri grants compensation for injuries due to toxic gases. For the other gases the reader is referred to the corresponding articles: "Carbon Dioxide", "Sulphur Dioxide", "Nitrous Gas", "Phosphoretted Hydrogen", "Gas-Works", etc.

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See also quarterly publication of the INTERNATIONAL LABOUR OFFICE: Bibliography of Industrial Hygiene.

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Gas-Works


For many a day it had been known that seams of coal and lignite, as well as substances of animal or vegetable origin, when buried or piled up in heaps were liable to give off gases capable of burning with a more or less luminous flame. But it was only between 1726 and 1729 that James Clayton, in the course of attempts to prove the accuracy of the hypothesis that coal gas is spontaneously produced by raising the temperature of a mass of heated coal in a closed vessel, obtained vapours which burnt on contact with a flame.

Between 1792 and 1805, W. Murdoch, in collaboration with Boulton, Watt and Samuel Clegg, perfected the distillation of coal and the accessory plant so that he was able to light up several large

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1 It should be recalled here that in large-scale industry special colour is applied to the piping in accordance with its contents (water, steam, compressed air, etc.).
Birmingham rope-works and other English factories. At the same time Philip Lebon, in France, distilled wood, following a similar method; in 1799 he took out a patent for a new method of using fuel more usefully, either for lighting or heating, and of collecting the different products. The first researches are those of Watson (1767), who dry distilled coal and obtained gas, coke, and ammonia.

The first use of coal gas for street lighting was made in 1813 in some districts of London; and in 1815 it was installed in a quarter of Paris by the firm known as the Chartered Gas Light and Coke Company, founded by a German, I. H. Winsor. Under the name "gas-works" are included especially works where coal is dry distilled, with the object of obtaining, as a principal product, gas for lighting and heating. On the other hand, under the name "coke-ovens" or cokeries are included works where the distillation of coal is carried out with the special object of producing metallurgical coke.

Finally, furnaces in which coke is burnt and furnaces in which it is partly burnt and partly distilled for the production of water gas, producer gas or Siemens gas, or poor quality gas (gaz pauvre), are known by the name of gas-producers or gasogenes 1.

However, in some works, especially if they are situated in localities where the supply of coal is difficult and costly, gas for heating and lighting purposes is obtained by the distillation of other fuel, especially lignites (see that article), peat, and wood. These works may also be called gas-works. The difference between these works, however, only consists in details peculiar to the furnaces and the technique of distillation; this is why it does not come within the province of this article to describe them separately. (As regards the distillation of wood, see article "Timber Industry", see also the articles "Acetic Acid", "Methyl Alcohol", and "Acetone").

In addition, at many gas-works — especially since the war — gas, before distribution to the consumers, is freed from an important part of such light gases as benzol and its homologues; this operation called debenzolating, is even made compulsory by some Governments, e.g. in Italy and France. In other works, coal gas is mixed, during or after preparation, with more or less water gas. Then there exist other works where the primary gasification of coal is carried out and where, by a single process, "bigaz", or double gas is produced. For this purpose retorts of special shape are used, the upper part of which contains coal and acts as a real distilling retort, while the lower part receives the coke, on to which...
play alternately currents of air and steam as in a producer (apparatus of Strache, Tully, etc.).

Each of these processes definitely modifies the amount of gas obtained from the distillation, as well as its composition, its illuminating and heating power. It would be very difficult to give a complete description of them in a few pages. Fortunately, these processes are more interesting from the technical and economical point of view than from the standpoint of health and sanitation; for (a) the composition of the gas obtained by these different processes is profoundly modified quantitatively, but scarcely at all qualitatively, and (b) the necessary processes present dangers which do not differ from those which threaten workmen in the preparation of gas by the ordinary or primitive method. This is why the present article is restricted to a description of this last method only, which is the one most used and which might even be called the classical method, and its description is completed by a simple account of the technical processes employed for the preparation of such industrial gases as water gas, producer gas, and for debenzolating, which now represent everywhere complementary operations in the coal gas industry.

On the other hand, such accessory industries as the preparation of sulphate of ammonia and of cyanides, which should be considered as independent chemical industries (see those articles), will not be dealt with here.

Products of the Distillation of Coal

By distillation two solid products are obtained and many volatile products. The solids are (a) coke, the residue of the process in the retorts, and (b) graphite, which is deposited little by little on the interior walls of the retorts; it forms a more or less thick layer, which should be removed periodically by raking.

Among the volatile products of distillation, some become condensed when the temperature of the gas falls and then separate spontaneously from the other products, but not all and these not always completely. They are in parti-

![Figure 121: Gas furnaces: condensers.](image)

cular water, tar, ammonia, and naphthalene.

Those products which remain in the gaseous state, being a mixture of gas and light vapours, constitute essentially illuminating gas. But before distribution to consumers, this gas should be freed, not only from residual traces of condensable products, but also from other elements which are inert or harmful.

Physical Properties of Illuminating Gas

This is a colourless gas, with a sharp peculiar smell capable of being reco-

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Gas-Works
nised, even when it is mixed with air in the proportion of 1 in 10,000. Its specific gravity varies from 0.350 to 0.550 (air = 1); a cubic metre of gas weighs from 0.465 to 0.549 kg., and on the average 0.530 kg. It burns with a luminous flame, giving off 10,269 calories per kilogram (Réclet), that is to say, from 4,500 to 5,500 calories per cubic metre when brought in contact with a flame or an incandescent body; it explodes when mixed with air in the proportion of 6 per cent. The tendency to explode depends upon the affinity existing between methane and oxygen, the maximum effect being obtained when 1 volume of methane is mixed with 2 volumes of oxygen.

Illuminating gas, as has already been seen, is a mixture of several gases and of vapours from certain easily vaporised liquids (benzol, etc.), which can be grouped as follows: (a) non-luminous gases: hydrogen (H), methane (CH₄), and carbon monoxide (CO); (b) luminous gases and vapours: ethane (C₂H₆), propane (C₃H₈), butane (C₄H₁₀), ethylene (C₂H₄), propylene (C₃H₆), butylene (C₄H₈), acetylene (C₂H₂), allylene (C₃H₄), crotonylene (C₅H₈), pentylene (C₅H₁₀), tyophene (C₄H₄S), benzene (C₆H₆), toluene (C₆H₅CH₃), xylene (C₆H₈O), stirene (C₆H₅CH=CH₂), indene (C₆H₅CH=CH₂), naphthalene (C₁₀H₈), acenaphthene (C₁₀H₈), fluorine (C₆H₆), pyridine (C₅H₄N), phenols (C₆H₅OH), and (c) inert or injurious gases, occurring as impurities: carbonic acid (CO₂), ammonia (NH₃), hydrocyanic acid (HCN), sulphuretted hydrogen (H₂S), oxysulphide of carbon (COS), nitrogen (N), sulphide of carbon (CS₂), sulphocyanogen (CNS).

Most of these substances are only present in traces. The most important elements quantitatively are: hydrogen, 42 to 55 per cent.; the saturated hydrocarbon (methane, ethane, propane, butane), 32 to 38 per cent.; carbon monoxide, 4.50 to 11 per cent.; carbon dioxide, 1.25-3.20 per cent.; nitrogen, 1-3 per cent.; aromatic hydrocarbon (benzene, toluene, xylene, stirene), 0.80 to 1.40 per cent.; and the heavy or non-saturated hydrocarbons (ethylene 2 to 2.5 per cent.; acetylene, 0.1-0.2 per cent.; propylene, 0.2-0.5 per cent.).

According to the researches of the Gas Society of Paris, carried out with different types of coal gas, the proportion of benzene in illuminating gas is almost constant: 20 grm. of benzene and 9 grm. of toluene and homologues per cubic metre. The proportion of aromatic hydrocarbons in volume was about 1.0 per cent. The heavy hydrocarbons (ethylene, acetylene, etc.), on the other hand, vary between 2.5 and 4.8 per cent. (in volume).
The proportions of the constituent elements of illuminating gas also vary, depending upon:

(a) **The quality of the coal.** — The greatest quantity of gas comes from bituminous coal, which gives a long smoky flame and is known in commerce as gas coal (French, Houilles à gaz; German, Gaskohle; Belgium, Charbons flenus de gaz; Italy, Carbont da gas).

(b) **The temperature.** — The evolution of vapours of condensable products begins as low as 50° C. Between 450° C. and 500° C., naphthalene is produced. The most suitable temperature for obtaining gaseous products lies between those at which the retorts glow with red cerise colour (about 800° C.) and with a yellowish white colour (about 1,300° C.). The gases given off have a lower calorific value in proportion as the temperature of production rises. If coal is subjected suddenly to a fairly high temperature (but not so high as to cause distillation by explosion), it gives off an abundance of aromatic hydrocarbons (xylene at 600° C.; toluene at 700° C.; benzene at 800° C.), which are the most luminous. This fact explains why in gas-works the retorts are charged when they are at a low red heat. Very high temperatures cause decomposition of sulphide of carbon and, on the other hand, favour the formation of sulphuretted hydrogen, carbonic acid, and oxysulphide of carbon, especially in the presence of steam.

(c) **The duration of distillation.** — Four to six hours are usually required; but most of the gas is obtained during the first three hours. The gas distilled at this phase has also a higher illuminating power than that obtained in the following stages, since it is rich in light hydrocarbons.

**Industrial Operations**

The extensive plant which goes to make up a gas-works can be grouped in two series: the first used for the production of gas and the second for its purification.

Production plant is always placed entirely in the open air or under roofing. Purification plant is also arranged under cover, but is often partly placed in large, closed, well-ventilated places.

**Transport**

In modern works the transport of coal from railway trucks or boats to the store-yards, as well as its distribution in the works, its crushing, the charging and emptying of retorts, including the transport of coke for feeding the producers and the removal of residue taken from the retorts and passed to the yards, are all carried out by such mechanical means as travelling bands, elevator buckets, crushing machines, and tilting trucks, which require a limited number of workmen.

**Furnaces and Gazogenes**

Furnaces directly fired, that is to say, those in which the high temperatures necessary for distillation are obtained by burning fuel, coke, or coal, in the actual chamber of the furnace which contains the retorts, or in another in direct contact with it, are only used in small or medium-sized works.

Large modern furnaces, on the other hand, are generally heated indirectly; they are called gas furnaces because they are fed by the gases from the gazogenes or producers.

These last are composed of large chambers of masonry, quite separate from the furnaces, where a current of air and a very small quantity of sprayed water is made to traverse at a very slow rate a large bed of glowing
coke of a depth of at least 1½ metres. In this way producer gas is obtained which is composed of carbon monoxide (28 to 33 per cent.), hydrogen (1.5 to 4 per cent.), carbonic acid (0.8 to 4 per cent.), and nitrogen (62 to 64 per cent.). This gas can be brought directly into the furnace chamber, where it burns when freshly mixed with warm air. Sometimes, as a preliminary, condensable products, especially the tar and ammonia, are recovered from the partial distillation which has taken place in the gazogene. The gases, while still very hot from the combustion which has taken place in the furnace, instead of being discharged into a chimney, are passed on to regenerators or recoverers of heat. These are composed of separate vertical chambers constructed with fire bricks arranged chequerwise, where the heat given off by these gases is used to reheat either the air which feeds the gazogene (the primary air), or the air which is introduced into the furnace to burn the gas of the gazogene (the secondary air). Regenerators can be installed for furnaces heated either directly or semi-directly.

The fuel used in gazogenes is composed of coke in small pieces or in the form of dust, or of lignite or peat; sometimes tar is burnt, and more rarely coal debris.

The retorts are tubes of fire-clay, rarely of cast iron, 3 to 6 metres long, elliptical in section or in the shape of D turned sideways (△) the diameter of which is about 0.50 m. to 0.35 m. They are arranged in series or batteries of 3-6-9 or more. The central part of the retort is enclosed in the furnace chambers; it is arranged either inclined, horizontal, or vertical. The two openings open on the outside wall of the furnace and end in a head of cast iron, which can be closed hermetically with a special iron door by pressure only or by luting the edges with clay.

The retort may contain from 100 to 400 kg. of coal, according to size. Over the lower opening, for the escape of the gas from distillation, is fixed a pipe, joined to a large horizontal cylinder called the hydraulic main (barillet), which is filled to about two-thirds of its diameter with water, which thus makes an hydraulic seal.

The charging of the retorts can be done by hand or mechanically. In the first case the coal is put in with a shovel, or with a tool called a spoon; in the second case the coal required to fill the retort is first collected in a funnel-shaped receptacle, or hopper,
from which it is transported in a tilting truck; the coal is discharged in a mass into the retort.

After the distillation is finished the lower door is opened, when the incandescent coke falls into an iron truck placed under the opening and containing a little water to assist in quenching the coke. The truck is then moved to a special place where the coke is completely quenched by a jet of water. Coke from horizontal retorts and sometimes also from other types can, however, be drawn by hand by the use of a kind of rake with a long handle.

In up-to-date plants, on the other hand, the discharge of retorts when it is not effected spontaneously, is carried out by a machine supplied with a jointed pusher worked by electricity. This pusher enters the retort from above as a piston and thus drives out the coke, which is collected on the opposite side on a travelling belt, or by an apparatus in the form of a tank called a carrier-extinguisher, because in it the coke is quenched by a jet of water and carried to the store-yards.

Purification of Gas

Gas produced in retorts must be freed from a great many inert or harmful substances which it contains. This purification is carried out by processes in part physical and in part chemical.

(a) Physical Purification

The following are the physical processes for purifying gas:

Condensation. — Gas bubbling through water in holders or in an hydraulic collector (as has been mentioned above) cools a little and deposits most of its tar and a part of its ammoniacal compounds — the sulphates, chlorides, and sulphocyanides. In order to cool the gas still further, it is made to pass through a long cast-iron pipe of large diameter called "a collector", and then through condensing or cooling apparatus called "organ stops". These latter consist of an iron tank half filled with water, in which stands a series of vertical pipes. Some baffle boards arranged in the tank make the gas circulate throughout the length of one pipe before passing to the next one. Sometimes the organ stops are replaced by a tubular refrigerator. In the condensers, the gas parts with tar, ammonia, and naphthalene.

Tar separators. — In order to free the gas completely from the last traces
### Manufacture of Coal-Gas and Its By-Products in Order of Size of Factories

#### Very Small Works
- Gas purified by the humid method
- Gas purified by the method
- Gas washed with water
- Gas purified by the method
- Purifying waste products
- Ammoniacal liquids

#### Small Works
- Gas purified by the method
- Gas purified by the method
- Gas purified by the method
- Gas purified by the method
- Purifying waste products
- Ammoniacal liquids

#### Average Sized Works
- Gas purified by the method
- Gas purified by the method
- Gas purified by the method
- Gas purified by the method
- Purifying waste products
- Ammoniacal liquids

#### Large Works
- Gas purified by the method
- Gas purified by the method
- Gas purified by the method
- Gas purified by the method
- Purifying waste products
- Ammoniacal liquids

#### Very Large Works
- Gas purified by the method
- Gas purified by the method
- Gas purified by the method
- Gas purified by the method
- Purifying waste products
- Ammoniacal liquids

### Final Products Envisaged

#### Chemical Formula

<table>
<thead>
<tr>
<th>Product</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphuric Acid 60%</td>
<td>H₂SO₄</td>
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<tr>
<td>Free Sulphur</td>
<td>S</td>
</tr>
<tr>
<td>Sulphocyanide of Ammonia</td>
<td>CS₂NH₂</td>
</tr>
<tr>
<td>Ferrocyanides</td>
<td>Fe₃(C₂O₆)₃</td>
</tr>
<tr>
<td>Prussian Blue</td>
<td>Fe₂(CNO₂)₃</td>
</tr>
<tr>
<td>Ferrocyanide Double Insoluble</td>
<td>NH₄(SO₄)₂</td>
</tr>
<tr>
<td>Sulphate of Ammonia</td>
<td>NH₄SO₄</td>
</tr>
<tr>
<td>Concentrated Ammoniacal Liquors</td>
<td>NH₄Cl</td>
</tr>
<tr>
<td>Chlorhydrate of Ammonia</td>
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<tr>
<td>Volatile Alkali</td>
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<tr>
<td>Liquid Ammonia</td>
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<td>Benzol 90%</td>
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<td>Benzol 50%</td>
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<td>Cumol</td>
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<tr>
<td>Solvent Naphtha 1:1</td>
<td>C₆H₆</td>
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<td>Produce Benzene</td>
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</tr>
<tr>
<td>Pyridine</td>
<td>C₅H₅N</td>
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<td>Phenol</td>
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<td>Cresols</td>
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</tr>
<tr>
<td>Naphthalene</td>
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<td>Oil from Washing of Benzol</td>
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</tr>
<tr>
<td>Creosote</td>
<td>C₆H₆O</td>
</tr>
<tr>
<td>Oil for Furnaces and Motors</td>
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</tr>
<tr>
<td>Oil from Washing with Naphthalene</td>
<td>C₆H₆O</td>
</tr>
<tr>
<td>Anthracene</td>
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<tr>
<td>Painting and Roofing Products</td>
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</tr>
<tr>
<td>Pitch</td>
<td>C₆H₆O</td>
</tr>
<tr>
<td>Graphite for Gas Retorts</td>
<td>C₆H₆O</td>
</tr>
<tr>
<td>Coke</td>
<td>C₆H₆O</td>
</tr>
<tr>
<td>Coke Dust</td>
<td>C₆H₆O</td>
</tr>
<tr>
<td>Iron Dust</td>
<td>C₆H₆O</td>
</tr>
</tbody>
</table>

### Raw Materials

- Coal (1000 k)
- Coke (700 k)
- Tar (50 k)
- Medium Oil
- Heavy Oil
- Anthracene Oil
- Pitch

### Products

- Disposable Coke for sale and making water gas (500 k)
- Coke Dust
- Iron Dust

### Notes

- (A. Grebel, Consulting Engineer)
- Reprinted from Chimie et Industrie, Vol. IX, Jan. 1923
of tar which it still contains in globular form, it is made to pass into another condenser or tar separator (condensateur à choc) invented by Pelouze and Audouin, which is composed of a bell turned upside down on water and containing two pairs of concentric perforated iron plates. The two plates of each couple are only $1.5\text{ mm.}$ to $2\text{ mm.}$ apart and are arranged so that the holes of one plate come opposite the part of the other which has no holes. The result is that when the gas, after passing through the holes of the first plate, strikes against the part of the second with no holes, it parts with the very minute droplets of tar which it still contains in suspension; then it passes through a second couple and there completes the purification by the same process.

**Naphthalene washers** ("Standard"). — Separation of naphthalene from gas is obtained by washing the gas in anthracene oil which is only moderately dense, or in creosote. This operation is done in an apparatus called a "Standard washer". This apparatus consists of a large horizontal cylinder of iron plates divided internally into three or more sections by baffle boards arranged parallel to the bottom of the chamber. The cylinder is traversed...
lengthwise by a shaft, on which are mounted discs for each compartment. To two parallel discs are fixed the ends of a large number of wooden lathes, so arranged in series that the spaces between one set of lathes come opposite the lathes of the next series. These discs revolve with the shaft and about a third of their diameter enters the liquid, so as to establish close contact between the oil and the gas. The gas circulates in the cylinder in the reverse direction to that taken by the oil, to which it gradually gives up the naphthalene it contains.

Ammonia washers. — Two types are used: scrubbers and standards. The first consists of two or three very high and large columns which are filled with coke. The gas enters from the bottom, whilst water falling from above, in the form of a shower, constantly wets the coke and dissolves the ammonia, especially the carbonate and sulphide of ammonia. The second, quite similar in shape to those used for naphthalene, are, however, made up of seven compartments and contain water instead of anthracene oil.

(b) Chemical Purification

This method chiefly permits of the separation of sulphuretted and cyanide compounds, such as H₂S, COS, HCN, CS₂, sulphoncyanides and sulphuretted hydrocarbons, and of carbonic acid (CO₂). The separation takes place generally in a single operation by passing the gas through a mixture (mixture of Laming, Deicke, Lux, etc.) formed of sawdust, ferrous sulphate (or natural limonite), sulphate of lime, and free ammonia. The lime fixes the sulphuretted hydrogen and the sulphides, forming sesquisulphide of iron and water [2Fe(OH)₂ + 3H₂S = 6H₂O + Fe₂S₃]. It should, however, be noted that a large part of the sulphuretted products have been already retained by the ammoniacal liquor. The lime fixes the carbonic acid; while the hydrocyanic acid, as well as the cyanides of iron, potassium and ammonia, become changed into ferric ferrocyanide (Prussian blue) and into sulphocyanide of iron. The mixture, arranged in layers of 0.5 m. to 0.6 m. in large tanks and closed by a cover with a water seal, is traversed by the gas. After use this mixture can be revivified by exposure to the air for two to three days and by frequent stirring; in this way the sulphur separates from the sulphides and the sesquioxide of iron hydrate is formed afresh. By suitable chemical treatments sulphur or pyrites, Prussian blue, sulphoncyanide of ammonia, and sulphate of ammonia can, in addition, be obtained from this mass.

The purified gas then passes through the meters and on into the reservoirs or gasometers, from which it is supplied to the consumers through gas-mains. From the hygienic point of view, the meters are not of any importance. The gasometers are composed of iron bell-containers of cylindrical shape placed over a deep pit filled with water; their movements, as they rise and fall, are regulated by counterpoises and slides on vertical rails. Gasometers without water seals are now constructed, for example, at Michigan City and at Flushing, where the container is fixed and the confined gas is put under pressure by a piston working inside the receiver, the piston moving according as the volume of the gas increases or decreases. Contrary to common expectation, these gasometers do not present special dangers. The gas which may escape by fissures due to corrosion or accidental perforations of the walls will burst into flame if it comes in contact with an incandescent body, but the pressure which is maintained in the interior of the gasometer does not allow air to enter; in consequence, the possibility of an explosion is almost eliminated — except, of course, under exceptional circumstances.

Toxicity of Gas

Even after purification, gas must be regarded as injurious to health whatever its strength, for it still contains many definitely poisonous elements. As a matter of fact, small traces of gas (0.25 per cent.) circulating in the atmosphere are sufficient to cause malaise; while a strength of 2 per cent. (in volume) may cause asphyxia. Non-purified gas is still more poisonous, as it contains, in addition, variable quantities of ammonia, hydrocyanic acid and cyanide (varying traces), sulphuretted hydrogen and sulphocarbon compounds (CS₂) and COS.

1 The distillation of 100 kg. of coal gives usually 18 litres of ammoniacal liquor at 3° B. It is admitted that 1° B. corresponds to about 5.9 grm. of ammonia per litre; consequently the total quantity of ammonia will be 24 grm. per litre. Very large variations (from 12 to 35 grm.) are, however, noticed. Ammonia is found in gas partly in the free state and partly in the state of salts of ammonia (carbonate, sulphide, thiosulphate, chloride, bicarbonate, sulphate).

2 It may be present in non-purified gas in a proportion of 0.38 to 0.78 per cent. in volume (Wright).

3 About 0.02 per cent. in volume.
Both purified and unpurified gases contain, moreover, large proportions of such irrespirable gases as hydrogen, 42 to 55 per cent.; carbonic acid, 0.59 to 2 per cent.; and nitrogen, 2.18 to 2.37 per cent.

The degree of toxicity of each element which enters into the composition of illuminating gas is not accurately known. If, however, they are considered by groups, and if account is taken of their strength in the gas, it is possible to draw up the following list in the order of danger: (1) carbon monoxide; (2) aromatic hydrocarbons; (3) non-saturated hydrocarbons; (4) inert gases; (5) saturated hydrocarbons.

Some gases classed as inert, such as HCN, CS₂, and H₂S, are, nevertheless, extremely poisonous, but they are found in gas in very small proportions.

The saturated hydrocarbons on the other hand, such as methane, although present in very high proportions, should be considered as less injurious than the other elements, for they are tolerated quite well by the system. It is a well-known fact that in certain coal mines, miners can even work where the atmosphere contains 9 per cent. of methane.

The element, which by its quality and quantity represents the most important index of the degree of toxicity of gas, is carbon monoxide. The aromatic hydrocarbons, although having theoretically a toxic action not less than that of carbon monoxide, are in reality less dangerous, on account of their lower percentages. The toxicity of carbon monoxide, which is already very high when it is a question of undiluted coal gas, is decidedly increased for mixtures containing water gas. In fact while it is an exception for pure gas to contain as a maximum of 40 per cent. of carbon monoxide, water gas, when it comes from certain qualities of coal, contains from 40 to 50 per cent.

**Dangers**

The sources of danger and ill-health are numerous for workers at gas-works as well as for the population in the neighbourhood.

**Dangers to the Workmen**

These will be considered by following the scheme of work; in this way the type of risk and its importance will be better illustrated.

(a) Danger arising during the transport of coal is represented by traumatic lesions, but this danger is not ordinarily very serious, for transport is effected in almost all gas-works by mechanical means provided with efficient protection against accidents.

(b) Coal heaped in stack-yards takes up a good deal of oxygen from the air and becomes heated, giving off carbon monoxide and water. Coal may also take fire from spontaneous combustion, especially when it is moist and in small pieces, or if it is rich in pyrites. The stack-yards have generally only roofs, so that the work of extinguishing does not present serious risks to the workers from burns and asphyxia. However it may be, these dangers can be easily avoided, except in the case where the workmen are obliged to enter the stack-yard to carry buckets of water necessary for extinguishing fire, instead of directing a stream of water on to the burning mass from a hydrant under pressure from the outside of the stack.

(c) When lighting up the furnaces, or the gazogene, an explosion may occur if gases from the preceding distillation remain mixed with air. The danger is a little greater with furnaces with gazogenes than with those with direct fire, which is explained by the different chemical composition of the gases formed.

(d) Keeping up the fire of the furnace or of the gazogene is hard and exhausting work, which causes the workers to breathe much coal dust and exposes them constantly to the action of great heat given off by the walls of the furnace, as well as to still greater heat radiated directly from the fire. Each time the door has to be opened — be it in coke or oil, to stir the mass, or to break up the hard surface formed by slag. It is on these occasions that burns are liable to occur with some frequency. The furnace workmen are also exposed to the effects of the products of combustion, which are very poisonous and very hot; but the escape of these products is much more important in the case of open furnaces or furnaces with direct fire, whilst it is of little importance for gazogenes, where a very strong draught carries the warm gases from the exterior towards the hearth by means of air blown in — right into the retort chambers — to the recuperators of heat and on to the chimney.

(e) Cleaning fire bars, the object of which is to remove incrustations which adhere to them, is always difficult, dangerous, troublesome, and unhealthy work. If it is done by hand, the workman has to rake the bars with a long and heavy slicing iron standing
before the opening of the furnace whilst the combustion goes on in the furnace, and fumes, gases, and cinders are given off. This operation is repeated almost every time that fuel is put on and is followed at least twice a day by a general cleaning of the fire bars and a raking out of the clinker. These two operations are very strenuous and last sometimes so long that the fire rake becomes red hot and soft. But if the Gill machine, mounted on a trolley — a device in which the raking instruments recall boring drills, and are worked by compressed air — is used, the operation only lasts two or three minutes.

In this case the workman is fatigued very slightly and is much less exposed to the injurious action of calorific radiations or to the asphyxiating effect of smoke and gases, for he can keep himself quite away from the opening of the furnace.

(f) Among the operations which present similar dangers it will suffice to mention: (1) periodical cleaning of smoke-flues, (2) repairing cracks or fractures which may occur in the retorts; and (3) the charging and emptying of retorts.

Another operation which is done close to the furnaces is raking out the clinker close to the furnaces is raking out the clinker. The three other operations have to be carried out without interfering with the work of the furnaces; in consequence the workman is obliged to endure very high calorific radiations. The repair of retorts takes an especially long time, for it involves luting cracks with fireclay and sometimes remaking more or less important parts of the walls by means of special tools. During all this time the workman is almost in contact with the opening of the retort which is at red heat (800° to 1,000° C.) and must breathe the gases of combustion which pass out of the clinker. These two operations are very strenuous and last sometimes so long that the fire rake becomes red hot and soft. But if the Gill machine, mounted on a trolley — a device in which the raking instruments recall boring drills, and are worked by compressed air — is used, the operation only lasts two or three minutes.

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The charging of retorts may be a long process when the coal is put in by shovel; but the workman can stand to one side, rather than in front, of the opening of the retort during a large part of the operation. He can thus partly protect himself against the effect of high temperatures. This operation exposes the workman to dust which is more or less abundant, but enables him to avoid the inhalation of poisonous gases. As has already been stated, charging can be done mechanically in a few seconds with a minimum of risk for the workmen; but in the less important works this operation is still done by hand.

More numerous and more serious are causes of injury to the men while emptying the furnaces. In the first place, if the workman does not open the door gradually, rapid mixture of gas with the air may cause an explosion; the gas which burns as soon as it comes in contact with air, bursts into a big flame, and when the incandescent coke falls on to the trolley, it gives off a dense cloud of hot gases, fumes, steam, and ashes, which spread to the adjacent parts and may be fatal to persons in the vicinity. The mass of coke from horizontal retorts and sometimes even from inclined retorts, does not fall spontaneously from the retort, and in that case it must be drawn with the fire rake when the works are not provided with the machine described above. Emptying a horizontal retort by hand takes about ten minutes.

If coke is collected by means of an extinguisher-transporter, it is carried by means of iron plates on a travelling belt, next to the extinguisher, which discharges coke through cracks, and the hot coke is carried on a travelling belt, next to the extinguisher, which discharges coke through cracks, and the hot coke is discharged to the stacks. The workmen who manipulate the machine are, under these circumstances, very little troubled by carbon monoxide and other gases. But if the transport is done by trolleys pushed by hand or by wheelbarrows, and if the coke is quenched on an ad hoc site manually by means of buckets or jets of water, it is obvious that the workmen will suffer considerably either from the heat or from breathing an atmosphere heavily laden with carbon monoxide and other gases.

For this reason emptying retorts and quenching the coke must be regarded as the most unhealthy and dangerous operations in the process of making gas. As a matter of fact, they are the causes which give rise to the greatest number of accidents and acute poisonings.

(g) During the different processes of physical purification of gas, the danger to the workmen is very small, for these operations all take place in pipes and apparatus which are hermetically sealed, and any leaks are immediately found and repaired. These leaks are detected either by the smell of the escaping gas, or by condensation of tar or the holes whence the escape of gas has occurred.
On the other hand, the part of the works where chemical purification is carried on presents danger from poisoning or explosion greater than that existing in the other departments of the works. The mixture of sawdust, lime, and iron, contained in the closed tank, to be used for absorption, when it is exhausted, that is to say, when it is no longer capable of absorbing the sulphuretted compounds or cyanides. (The exhaustion is at its maximum when the gas coming off blackens acetate of lead paper, which shows that the mixture is no longer absorbing the sulphuretted hydrogen.) A cubic metre of the mixture is usually sufficient to purify 50,000 cubic metres of gas. When the moment comes to renew the mixture in the closed tank, the cover is raised; with the result that all the gas which it contains, and this always means quite a large number of cubic metres, is sent into the surrounding atmosphere, constituting a very serious danger from poisoning and explosion. The workmen employed in taking out the exhausted mixture with the shovel and conveying it in wheelbarrows to the stacks, being obliged to stir it frequently with the object of revivifying it (work which is done entirely by hand), are seriously exposed to risk of poisoning, as the mixture retains gas for a long time in its bulk. (In Holland a case of gangrene of the hand has been reported in a workman who handled the mixture called “Lux” — oxihydrate of iron and lye-wash.)

(h) Other operations in the works must also be mentioned, such, for example, as periodical cleaning and repairs of piping or the apparatus through which the gas passes. This work, which is generally carried out near installations on the ground level and in the open air, is certainly less dangerous than when it has to be done in underground mains in streets or inside buildings. Nevertheless, habit too often makes the workmen forget the risk and neglect the precautions necessary to avoid poisoning, fires, or explosions. The most dangerous operations are those which require the workmen to enter the apparatus which has contained and may still contain gas.

**Danger to the Neighbourhood**

The same causes which render the making of gas unhealthy and dangerous for the workmen render it also harmful and a special nuisance to the neighbourhood. The dense and irritating smoke discharged from the chimneys, the coal dust, the emanations from the ammoniacal liquor and tar, and the gas which escapes from the purifiers, retorts, and joints of the piping alter more or less the physical and chemical properties of the atmosphere in the vicinity of gas-works. The pollution of the air is indicated by the characteristic odour which is noticed in the vicinity of these works, sometimes even at some distance. The gas from gazogenes, although injurious to the same degree, is, however, colourless. On the other hand, it is a very rare occurrence for buildings in the neighbourhood of gas-works to suffer injury by fire or explosion originating within the works.

If the waste water from this industry is not discharged into an adequate drain, but is run into open channels, or into small streams, or distributed over the ground, it gives off ammoniacal gases into the atmosphere in the zones through which it passes. However, these gases can be considered as inoffensive, as their quantity is so small. On the other hand, the waste water may, in accordance with the nature of the soil, cause pollution of wells and cisterns even at a considerable distance; or may render running water unfit for drinking or irrigation, and injurious to fish life, for it contains, in addition to ammonia and its salts, Prussian blue, ferrocyanide of calcium, oils of tar, and naphthalene.

**Water Gas and Producer Gas**

If a current of air or a mixture of air with a very small quantity of steam is passed through a large mass of incandescent coke (or even of lignite or peat) or anthracite, with a depth of 2 to 3 metres, in gazogenes or producers, such as have just been described, a gas is obtained called producer gas, which contains in volume from 62 to 64 per cent. of nitrogen, from 28 to 33 per cent. of carbon monoxide, and small quantities of hydrogen (1.5 to 4 per cent.) and carbonic acid (0.8 to 4 per cent.).

This gas resembles that which forms in blast furnaces and has quite a high calorific value. By modifying in a suitable manner the shape and certain arrangements of the gazogen, as well as the proportions of air and steam, and the draught, other gases are obtained having similar properties, but of less calorific value, which, on account of this quality, are called poor gases (gaz pauvres).

But when a layer of coal, rendered incandescent by the passage for some
minutes of a strong current of air, is traversed in the reverse direction, and for a period twice or three times as long as the preceding, by a full current of steam, another gas is obtained, viz. water gas, which has a calorific value much higher than producer gas (2,600 calories) and which contains on an average 45 to 50 per cent. in volume of hydrogen, 38 to 45 per cent. of carbon monoxide, 4 to 7 per cent. of carbonic acid, 4 to 5 per cent. of nitrogen, and about 1 per cent. of oxygen. This gas, after being purified in scrubbers and cooled, gives an excellent light when burnt on burners with incandescent mantles; and, although it gives off little more than half the calories of coal gas, it is, nevertheless, able to produce higher temperatures, for it burns with a much smaller quantity of air. That is why it is used with advantage in the autogenous soldering of iron and replaces the oxygen or oxyacetylene flame.

On account of its heating properties it is mixed, in almost all works, with coal gas, or it is produced with it in the same retorts (bigaz or double gas).

As was mentioned at the beginning, the operations required for the production of water gas and producer gas in gas-works do not add any new health risks for the workmen, although they naturally may increase the number of the sources of these dangers.

Debenzolating

Almost every works now practises the extraction of a part of the light hydrocarbons from coal gas, but this extraction is, however, limited to about 15 grm. per cubic metre, for it robs the gas of almost 40 per cent. of its lighting power, whilst it only diminishes its heating power by 6.5 to 7.5 per cent. The first extraction is of little importance when the gas is burnt in burners with incandescent mantles, and the second is largely compensated for by the successive addition of water gas.

Debenzolating is carried out by different methods: usually the gas is made to circulate rapidly in petrol or oil of schist, that is to say, in other hydrocarbons which have a boiling point higher than that of benzol and its homologues (toluol, xylol). Sometimes it is sufficient to keep the gas in close contact with these oils for a certain time for the absorption of benzol to occur. Another system consists in washing the gas in tar which has been heated or deprived of its more volatile elements.

Benzol is then separated by fractional distillation of the oils or tar in which it has been absorbed.

All these operations take place in closed apparatus, and in consequence do not present any particular dangers for the workmen, except in the case where surcarbonated liquids or pure benzol have to be collected and removed, or in cleaning the apparatus. It is advisable to bear in mind that benzol vapour forms an explosive mixture with air — when the proportion is 4.29 to 100 — and that it can be absorbed even through the skin, especially when in contact with clothes saturated with benzol.

Statistics

The number of workmen employed in gas-works is very small compared with the quantity of coal worked, for most of the operations are done, as has been said, mechanically.

The condition of health of these workmen is not very bad. Signs of slight poisoning, such as malaise, headache, vertigo, vomiting, and inco-ordination of movements, are not uncommon, but death from poisoning is rare.

Figures compiled by Hanauer show that in all the German gas-works during nineteen years, 1885-1903, only 37 deaths from poisoning were reported, of which the greater number occurred in small works, where supervision is generally less strict than in large ones. The figures for other countries which show deaths from illuminating gas do not show how many of these cases occurred among workmen at gas-works and how many are to be attributed to the domestic use of gas or to suicide.

According to a report by Stevenson, of the Registrar-General's Office in England, presented to a commission appointed by the Board of Trade in reference to the application of the Gas Regulation Act of 1920, the number of persons who died from poisoning in England and Wales during twenty-two years (from 1898 to 1919) was 1,300, with an average of 60 a year. However, from 1913 to 1919 the number of deaths was higher (632) with an average of 90 a year. This increase coincides with the permission to increase the proportion of water gas in coal gas and in consequence of carbon monoxide. During the same period, 1913-1919, the death rate in the large towns reached 3 per million — in London it was even 3.1 — as against a rate of 1.9 for the whole country.

In the United States the Gas and Electric Commission of Massachusetts has published some statistics, according to which from 1914 to 1919 the deaths from poisoning due to coal gas among consumers were 7.3 per million inhabitants — a death rate more than double the English rate. But among consumers of gas supplied by works which distribute water gas added to coal gas, the death rate reached the average of 4.2 per million with a maxi-
mum of 59.3. Here again, however, the figures do not refer to deaths of workmen engaged in this industry.

No special industrial diseases of workmen employed at gas-works have been described. It seems also that they are not even affected by the diseases found among tar and pitch workers. Although many coals contain arsenical pyrites, no case of arsenical poisoning has ever been noted among these workers.

According to Jéhle, 1900, the annual death rate from all causes among workmen in gas-works at Berlin and Vienna was 1.56 per 1,000 against 1.3 found among members of the Sickness Insurance Office and 1 per 1,000 among those of trade friendly societies.

The sickness rate, without taking into account deaths due to accidents, was 48.7 per cent. at Vienna against 27.4 per cent. among the members of the Local General Sickness Insurance Office. It was 34.1 in Berlin in 1901. Petersen, of Copenhagen, found, however, a sickness rate twice as high as among other classes of workmen.

The commonest diseases are: diseases of the respiratory organs, with a rate of 20.16 against 4.40; and accidents. Tuberculosis is rare. At Berlin the following figures have been recorded: respiratory diseases, 21 per cent.; digestive organs, 11, accidents, 16. At Magdeburg, according to Schutte, 20 per cent. of the cases were due to diseases of the respiratory organs, 18 to those of digestion, 11 to rheumatism, 12 to accidents, and 10 to poisoning.

According to the figures of the Local Sickness Office of Leipzig, the cases of sickness registered among workers at gas-works would be, taking them altogether, more than 20 per cent. above the average. Respiratory diseases show a figure of 30 per cent. Those of the digestive organs and accidents show 50 per cent. Tuberculosis, on the contrary, caused about 30 per cent. fewer cases than the average. The number of cases of muscular and articular rheumatism seem to be equal to the average. The workmen, aged from twenty-five to thirty-five years, furnished a smaller number of sick than other age groups, but of a much more serious nature.

According to the figures of the Office of the Sickness Insurance Office the sickness and death rates were as follows:

<table>
<thead>
<tr>
<th>Per 1,000 members</th>
<th>Per 1,000 of the group members</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workmen at gas-works</td>
<td>All occupations</td>
</tr>
<tr>
<td>Number of cases of sickness</td>
<td>675.7</td>
</tr>
<tr>
<td>Number of days of sickness</td>
<td>10,840</td>
</tr>
<tr>
<td>Number of deaths</td>
<td>7.65</td>
</tr>
</tbody>
</table>

The frequency of diseases per 100 members and for each age-group is as follows:

| All causes | Respiratory diseases | Digestive apparatus | Diseases of locomotor apparatus | Diseases of nervous system | Infectious diseases | Diseases of skin | Diseases of circulatory system | External wounds |
|-----------|---------------------|---------------------|---------------------|---------------------|---------------------|----------------|----------------|----------------|----------------|
| All occupations | 44.4 | 6.6 | 5.9 | 7.4 | 9.7 |
| Workmen at gas-works | 60.6 | 8.2 | 9.8 | 12.7 | 13.1 |

The death rate from tuberculosis, which is 3.3 per 1,000 among workers of all trades, is only 1.4 among the workers at gas-works.

As statistics very often do not give precise figures on industrial sickness in relation to the exact occupation of the sick worker, Chajes has tried to combine the evidence regarding gas-workers by using the figures furnished by the Industrial Sickness Insurance Office of the four gas-works at Berlin, comparing them for the years 1913 and 1920 with the figures of the sickness societies:

<table>
<thead>
<tr>
<th>Sickness</th>
<th>Percentage of sickness found, in relative proportion, among</th>
</tr>
</thead>
<tbody>
<tr>
<td>of gas workers</td>
<td>of members of sickness societies</td>
</tr>
<tr>
<td>1913</td>
<td>1920</td>
</tr>
<tr>
<td>Cases of sickness</td>
<td></td>
</tr>
<tr>
<td>of which:</td>
<td></td>
</tr>
<tr>
<td>Traumatic lesions</td>
<td>515</td>
</tr>
<tr>
<td>Respiratory diseases</td>
<td>532</td>
</tr>
<tr>
<td>Diseases of locomotor apparatus</td>
<td>591</td>
</tr>
<tr>
<td>Digestive apparatus</td>
<td>573</td>
</tr>
<tr>
<td>of nervous system</td>
<td>152</td>
</tr>
<tr>
<td>Infectious diseases</td>
<td>856</td>
</tr>
<tr>
<td>Diseases of skin</td>
<td>573</td>
</tr>
<tr>
<td>of circulatory system</td>
<td>67</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>14</td>
</tr>
</tbody>
</table>
Whilst per 100 members of sickness societies an increase occurred, for the same years, from 57 to 66 per cent., the increase per 100 workers at gas-works was from 45.4 to 76.7. A great increase is shown also by diseases of the locomotor system, diseases of the skin, and especially by infectious diseases.

During the period 1920-1925, 26 cases of epitheliomatous ulceration due to tar or pitch (of which 7 were fatal) were noted among the workmen at English gas-works.

DETECTION OF ILLUMINATING GAS IN THE AIR

Besides carbon monoxide, other poisonous products must be taken into account, such as ethylene, formene (methane), propylene, and acetylene. From the point of view of detection, it is rare that a complete analysis of the atmosphere has to be made. Generally the search is restricted to verifying the presence in the air of important quantities of such gaseous hydrocarbons as ethylene and formene (see these articles).

HYGIENE

Analytical consideration of the different technical operations and of the most important causes of injury particular to each, enables the following conclusions to be drawn:

(a) Workmen employed in stoking the furnaces and gazogenes, in cleaning the fire bars and the smoke flues of the producers, in charging and emptying the retorts, in repair work, and in transporting and quenching coke are exposed to the effect of high temperatures in the form of radiant heat.

(b) Coal dust and ashes are inhaled chiefly by workmen employed in moving these materials, and by men who manage the fires, clean the flues, rake out the graphite from the inside of the retorts, charge and empty the retorts, and move and quench the coke. The skin and clothes of these men are obviously soiled by these dusts.

(c) The men employed in the vicinity of the furnaces and retorts are very exposed, both to rheumatism, which is fostered by the sudden changes of temperature, and to digestive troubles, since they are obliged to quench their thirst by drinking large quantities of liquid.

(d) Danger of asphyxia from breathing the gas, and risk of fire or explosion, exist at any stage in making and purifying gas. The most serious danger is met with in closed workplaces, especially if they are of limited space, and for the men employed in quenching coke, in the chemical purification of gas, in cleaning the physical purifying plant, and in the mains and gasometers. The coal stores, when slow combustion (oxidation) takes place, or a fire breaks out, present a source of danger from asphyxia and burns. The evacuation and transport of benzol, the emptying of tanks containing Laming mixture and stirring to revivify it, and also the extraction of tar from the pits, are all very serious sources of danger from asphyxia.

From the prophylactic point of view, the correct construction of the works is of first importance. All the plant necessary for making and purifying gas, including the storing of coal, the gazogenes, the tanks in which tar and ammoniacal liquor are collected, and the apparatus for debenzolating should be in the open air, or under open roofing. Closed places can only be allowed for the installation of part of the plant for physical purification, such as for the separation of tar, and washers for ammonia and naphthalene, and for meters and pressure gauges — and this only on the condition that the accommodation is very spacious and supplied with numerous openings and constantly ventilated.

The tanks for chemical purification, on the other hand, must only be under roofs and must form a separate section removed from all others. With the object of rendering the work less of a strain and avoiding damage due to excessive heat, as well as risks of poisoning, manual labour should be replaced by machinery. This is a prophylactic measure of first importance.

The measures quoted above concerning the movement of coal, the charging and emptying of retorts, the quenching and transport of coke, and raking out the fire bars, are also important. Other special measures, in addition, should be adopted, such as, for example: devices for raising the cover of closed tanks used for chemical purification by means of a crane (not by hand); for driving back the residual gases by mechanical ventilators before evacuating them; for keeping active the draught in the furnaces and maintaining a negative pressure; for injecting water into the gazogenes; for collecting, putting in barrels, and moving benzol to the places for debenzolating, without upsetting or exposing it to the air.

It is also important that the scheme for charging the gazogenes should provide for a platform protected by a balustrade and that the opening for charging is provided with a narrow
throat which does not allow the gases to escape at the time of charging.

Continual supervision of all the operations, as well as the detection and stopping up of gas leaks, are equally important.

In a word, very strict rules must be drawn up and enforced concerning the conduct of the workmen in all operations. Smoking must be strictly prohibited, also having matches on the person, or using lighted lamps which are not protected by metallic gauze (miners' lamps), unless electric incandescent lamps are used; the men must also be prohibited from standing near the openings of furnaces and retorts when opened any longer than is strictly necessary for each operation; from approaching the purifying tanks after the lids are raised until the gas has been removed by a current of air, either natural or artificial; from moving benzin in open receptacles or allowing it to fall on the ground or on their clothes. Workmen must never be allowed to work singly (always in pairs). They should wear a safety belt when they take out the Laming mixture from the tanks, when they enter flues or apparatus for repairs, or for cleaning the tar condensers, or nephthalene and ammonia washers, when they take out tar from the tanks or enter the storage tanks for ammonical liquor, or a gasometer already emptied of gas.

Before entering tanks, works mains, or closed tanks, it is indispensable to make sure that the air can be breathed by lowering a cage containing a bird, a mouse, or a rabbit.

Among other measures to be adopted the following should be mentioned. The absolute exclusion of women and young persons, of persons suffering from respiratory diseases, cardiac and such circulatory diseases as arteriosclerosis, of alcoholics and generally of the debilitated: the adoption of a short working shift for workmen employed at furnaces or retorts, for they are subjected to trying, heavy, and very unhealthy labour (high temperature, smoke, gas, etc.); the provision for the whole personnel of facilities for personal cleanliness, such as douche baths, lavatories, working clothes, and changing rooms; the wearing of respiratory apparatus as protection against gases and dust, of safety belts, of spectacles or goggles with coloured glasses for protecting the eyes or face against light and heat radiations, and of leather aprons; the provision of fresh beverages; the organisation of a first-aid service in case of burns or asphyxia etc.; the provision of oxygen under pressure, or of a mixture of oxygen and carbonic acid.

With a view to protecting the neighbourhood, gas-works should be situated if possible in the open country and in any case at some distance from dwellings.

Smoke-consuming apparatus should be applied to the chimneys.

Simple and economical means for the purification of waste waters are not known. It involves studying complicated methods of chemical disintegration, but it is certainly better to distribute these waste waters on land in places where they cannot pollute superficial or underground drinking water, after they have been retained for some time in the settling tanks.

LEGISLATION

The work of women and children is subject to the same arrangements as those laid down for work which exposes persons to the danger of poisoning by gases (see that article).

Among the regulations for gas-works may be mentioned the British Regulations of 11 July 1923, concerning the manufacture of chemical products, which applies also to gas-works; the Greek Royal Decree of 29 September 1922 relating to the establishment and equipment of industrial concerns, etc.; the Indian Factories Ordinance of 2 October 1919 (see that article).

The Dutch law provides for compulsory notification of cases of inflammation of the retina and optic nerve, as well as cases of conjunctivitis arising among workmen at gas-works. The expression "poisonous gas," adopted by the legislation of Missouri and other countries, probably covers also every kind of poisoning in the gas-lighting concerns. Poisoning by the products of the distillation of coal is compensated in several countries (see the corresponding articles).

BIBLIOGRAPHY


Glanders
(Farcy)

Glanders is a contagious disease which chiefly affects the horse, the ass and the mule. It may, however, affect also the dog, the cat, the goat and the camel and can be transmitted to man by these animals or by infected human beings.

Glanders is due to a specific bacillus — Bacillus Mallei — which is in the form of an upright or slightly curved immobile stick which is not sporogenous. In cultures it produces a toxic substance, mallein, which, obtained in the form of a filtrate from cultures killed by heat, is employed as a means of confirming the disease in cases where it exists in a latent state.

Glanders is an accidental disease in man. Except for rare exceptions, the victims are people engaged in occupations which necessitate direct or indirect contact with horses. The older statistics of Bollinger relating to 106 cases comprised the following: 66 stable boys and coachmen, 6 knackers, 6 horse-butchers, 10 veterinary surgeons, 4 doctors, 3 soldiers, 2 horse-dealers, 1 anatomy-room assistant, 1 blacksmith and 5 persons described as engaged in various occupations. The case of glanders reported by Hoke (1907) affected a veterinary surgeon (laboratory infection), Pieraccini’s case (1905) being an agricultural labourer.

Handling of horsehair may also involve exposure to glanders infection.

Contamination may take place by way of the skin (scratches, simple friction) or by the nasal or conjunctival mucous membrane.

The buccal mucous membrane may also serve as a means of entry and the gastro-intestinal passage has been considered as an important way of infection (Römer). There have finally been noted cases of contamination following on bites (Landouzy, Collie). Though contamination generally takes place by direct means, there has nevertheless been quoted the case of a laundress infected by handling the linen of a coachman suffering from chronic farcy (Elliotson).

Contagious matter generally consists in nasal discharge, pus from cutaneous ulcers and, in the case of slaughtered animals, glanders nodules and other lesions of the internal organs. The nasal discharge is particularly dangerous, for the animal in snorting secretes it around him, thus infecting all surrounding objects, the walls of the stable, box, etc., in which he is situated.

Glanders presents two distinct forms of evolution: acute and chronic.

Acute glanders has an incubation period of two to three days, accompanied by general symptoms (discomfort, anorexia, headache, articular pains and nausea) which are followed by symptoms typical of the disease, consisting essentially in swellings and ulcers, at the commencement of the site of infection, followed by lymphangitis and painful adenitis connected with the regions affected. The disease finally becomes generalised, with production of pasty tumours with a tendency to suppuration, painful spots and ulcers, and an articular discharge accompanied by fever, swelling of the spleen and often of the liver. Between the sixth and twelfth day the temperature attains a maximum, and an eruption breaks out on the face and extremities and especially on the buccal, nasal and conjunctival mucous membrane. This at first consists in red patches which become changed into papulae, then into pustules, sometimes umbiliform as in smallpox. Finally, there appear symptoms of nasal glanders which, in certain cases, occur before the commencement of ulceration and destruction of the cartilages and nasal bone, and discharge of a thick muco-purulent secretion, often mixed with blood. Further, there have been described specific lesions of the tonsils, the gums and the larynx, and localised inflammation of the respiratory system (bronchitis, broncho-pneumonia). Death mostly occurs after illness lasting two or three weeks.

Chronic glanders, also known as farcy, is of longer duration (two years and longer) and develops in a fairly vague form which may lead to error in diagnosis (Reverdin and Grumbach). It is usually a case of intermittent pain in the joints and the appearance...
of more or less serious nodules in the skin and muscles, especially in the peri-articular regions. These nodules finally suppurate and heal only to be replaced by other similar formations in other parts of the body. Apart from possible recovery, chronic glanders presents two distinct types of evolution: development into the acute form with fatal results, or development towards mixed infections in regard to which prognosis must be made with the greatest reservation. Under the latter circumstances, mortality occurs in about 50 per cent. of the cases.

Diagnosis of the disease must be effected by the aid of bacteriological methods or serological reactions. The maltein test may be used in the case of latent glanders.

Hygiene and Prophylaxis

Means of prevention of glanders are based, on the one hand, on personal hygiene of workers most exposed to such infection (cleanliness, precautions in the cleaning of animals, immediate treatment and protection of skin wounds) and, on the other hand, measures of sanitary control — immediate slaughtering of sick animals, rigorous isolation of suspected cases under very strict hygienic conditions up to the point of positive diagnosis, careful disinfection of stables and of all materials, objects or instruments having been in contact with sick animals, etc. All these measures are further completed by sanitary supervision of healthy animals, especially itinerant horses, cart horses, etc. Finally, even in face of reduced chances of incurring the infection, immediate treatment should be given to any less exposed workers who, on account of their occupation, are exposed to the risk of catching infection from animals suffering from glanders.

Legislation

Glanders of occupational origin is subject to compulsory notification in Bavaria, Brazil (agricultural workers), the Netherlands, Poland, U.S.S.R. It is compensated as an occupational disease in Austria, Canada (Alberta, New Brunswick: contact with animals or carcases of animals having suffered from glanders), Great Britain, Hungary (agricultural workers), and the United States (States of Minnesota, Ohio and New York).

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Glass Industry


Technical Data

Chemically glass is a mixture of silicates obtained by fusion at high temperature. According to their composition, a large number of varieties of vitrified products can be distinguished from ordinary window glass and commoner glass used for making certain bottles up to enamels, crystal glass, Strass, and the majority of artificial precious stones.

Silicates of soda or potash are found in the different kinds of glass, and in varying proportions, associated with silicates of lime, lead, zinc, iron, manganese, magnesium, etc.

By varying the composition the glass is given the most advantageous qualities for the purposes it is meant to serve. Lime, alumina, magnesia give hardness; iron, zinc and, above all, lead give the opposite qualities. The average composition of some glasses is as follows: ordinary glass, 72 per cent. silica, 15 per cent. soda and 13 per cent. lime; plate glass, 65 per cent. silica, 17.5 per cent. soda and the same proportion of magnesia; flint glass, 54 per cent. silica, 35 per cent. lead and 11 per cent. potash.

The green or brown colour of certain kinds of bottles is due to compounds of iron and other impurities in the sands used.

To remove the colour from glass a small quantity of manganese dioxide is added (glass workers' soap), which oxidises the organic matter and converts the protoxide of iron into the less coloured sesquioxide. Sometimes, with the same object of removing the colour, arsenious acid, nitrates, nickel, ceriums, etc., are used. And the carbon also, introduced in the form of carbonate, gives off CO which decomposes the sulphate of soda forming sulphur dioxide.

Glass is artificially coloured blue by oxide of cobalt, violet by manganese oxide in excess, turquoise blue by oxides of copper and tin, and green by oxides of iron and copper. Nickel, uranium, selenium and chrome are also used for colouring purposes. "Strass", which is a flint glass containing more than 50 per cent. of lead, resembling the diamond, serves as a base for glass in imitation of precious stones: for the ruby and topaz it is combined with
antimony and gold (purple of Cassius),
for the sapphire and amethyst with
oxide of cobalt, for the emerald with
oxides of copper and with chrome, etc.

If sand from the seashore, lime and
carbonate of soda are fused at a high
temperature in the proper proportions,
pulverised and intimately mixed, the
following changes are observed: at red
heat the mass agglomerates (from loss
of water of crystallisation); when cooled
in this state it is called “frit”. If, on
the contrary, the heat is increased, the
mixture becomes pasty and more or
less fluid: this is “the metal”; at a still
higher temperature the mass is quite
liquid and is called “fined glass”. This
is the moment at which, when cooled, it
acquires its maximum of transparency.

If the heating is continued for too long
a devitrification takes place, which
makes the mass progressively opaque.

Refined glass, if too rapidly cooled, is
in an unstable molecular state: it cracks
irregularly either in a way apparently
spontaneous or under the influence of
slight shock. To remove this defect
from the glass it undergoes the process
of “annealing”, which consists in put-
ting it in progressively cooler and cooler
furnaces. Manipulation of glass is
facilitated, when it is hot, by the pro-
property it possesses of remaining in a
pasty state during a good part of the
time taken in cooling. The duration of
this ductility is closely bound up with
the proportions of soda and potash
which it contains.

Some glass objects are “dipped”.
Dipping is done after annealing by
quickly plunging the article at a tempe-
rature of 200°-250° C. into an oil bath.
The dipping confers on the glass special
properties of elasticity and resistance
to shock.

There may now be mentioned, with a
view to avoiding returning to the sub-
ject, the composition of some special
glasses, such as quartz glass, which is
nothing other than pure silica fused in
an electric furnace. It is used for making
lamps for ultra-violet rays; laboratory
apparatus capable of resisting fire, heat-
glass made of borosilicate of aluminium
and soda (known as Pyrex) the manu-
facture of which is easier than quartz
glass and also resists brisk and con-
siderable changes in temperature.

Optical glass is divided into two prin-
cipal classes: flint glass, a glass with
a basis of lead, and crown glass,
a potash glass with a basis of silica
and lime.

Preparation of the Raw Materials

Whatever the kind of glass to be
made, the substances entering into its
manufacture are in a fairly divided
state and intimately mixed together.
Where this is not done, they are
subjected to mechanical grinding.

If sand from the seashore, lime and
carbonate of soda are fused at a high
temperature in the proper proportions,
pulverised and intimately mixed, the
following changes are observed: at red
heat the mass agglomerates (from loss
of water of crystallisation); when cooled
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the contrary, the heat is increased, the
mixture becomes pasty and more or
less fluid: this is “the metal”; at a still
higher temperature the mass is quite
liquid and is called “fined glass”. This
is the moment at which, when cooled, it
acquires its maximum of transparency.

FIG. 128.—Gathering the glass.

(Photo Kela, Brussels.)
Mixing or preparation of the batch is done either by hand with a spade or mechanically in closed apparatus—sometimes under a negative pressure. This apparatus generally consists of a mechanical mixer from whence a chain with buckets conveys the raw material, after sieving, to the discharging place. Sometimes the mixing is done wet; it is then dried before use. A certain quantity of cullet (glass debris) is generally added to the prepared mixture.

The Furnaces of the Glass Industry

Besides electrical furnaces, which are only occasionally used, a fairly large number of varieties of furnaces are in use which can be comprised under two principal types: pot furnaces and tank furnaces.

Pot Furnaces

This type of furnace may be represented in the form of a sphere with thick walls made of refractory materials, divided internally at the level of its horizontal diameter by a circular ledge of the same material. The interior half of this sphere is itself divided into two parts, one superposed on the other. The lower part serves for the hearth and is built over a space effectively allowing the cleaning of the grill; in the free part of the lower hemisphere the gases from this producer collect. They meet a current of air coming from the outside and re-heated either by recuperators or by passage through the checker work which surrounds the hearth. The gaseous mixture then penetrates through a central opening in the circular ledge and burns under the curved roof or crown formed by the upper hemisphere.

The “pots” arranged circularly at equal distances apart on the ledge are crucibles of refractory materials and have a varying capacity (up to a useful charge of 800 kg.) and the mixture to be vitrified is placed in them. In front of each of these pots is a hole in the wall of the sphere (glory hole) which allows the molten metal to be gathered. Pot furnaces are used in glass and bottle works as well as in the manufacture of coloured glass, special glass and enamels.

Tank Furnaces

Like pot furnaces these also are reverberatory furnaces. They have a very drawn-out form, are heated by independent gas producers and provided with recuperators. A tank furnace is essentially a long rectangular structure of considerable size (150...
square metres in superficies) constructed of refractive materials and covered with a vaulted crown of the same materials. On the long sides of the rectangle near one another are the openings both of the gases brought through the checker work from the producers and of the external air which has been heated by the recuperators. The mixture of these burning gases traverses the furnace horizontally at a certain height above the floor, with a periodical reversal of the direction of the current, that is, the openings in the checker work on one side serve at one time to bring in the gases and at another to remove them. The floor of the tank furnace is externally cooled by a current of air in such a way that it is entirely covered by a layer of solid glass about a metre in thickness. In this layer of glass the fused metal floats along from the end where the charging of the raw materials is done to the end where the metal is gathered. One or more dams divide the furnace transversely and the temperature varies from one part to another. The glass raised to 1,400° or 1,500° C. in the first part of its passage is brought down to 1,000° C. at the point where it is gathered. At this end the workplaces are arranged in a half circle. Tank furnaces are used for the manufacture of sheet glass bottles and certain kinds of rolled glass. Sheet Glass

Sheet glass (French: verre a vitres, German: Tafelglas), manufactured by hand, is glass that is blown into what are called "cylinders" or "muffs". The workplaces situated at the end of a tank furnace before a glory hole consist of raised platforms separated by rectangular pits several metres deep; these are called "elongating pits". Each of the workplaces is occupied by a team of workmen working in concert. One of them (the "gatherer" or "first helper") gathers the glass by means of a blow pipe which is a tube of iron about 2 metres long, protected against the heat at the handle. The assistant commences the preliminary operation called "parison" by blowing into the tube to make a cavity in the pasty mass. He passes the tube then to the "second helper" or "snapper" who completes the parison by adding more incandescent glass and making it even by the action of his breath and the gyration movement of the mass in a hole hollowed out of a block of wet wood. The parison then passes to the blower, who by blowing and various movements above the pit converts the vitreous mass into a long hollow cylinder. All that is then necessary is to crack off the end pieces to make the "muff" and "cylinder" of a length varying from 1½ to 2 metres, and of a
diameter of 30 to 40 centimetres. The cylinder carried by hand to the flattening oven, generally by women, or carried mechanically, is slit by a cut with the diamond along one of its sides. It is introduced into the flattening oven, where it is reheated. Thanks to the softening it undergoes it is widened progressively and smoothed on the floor of the furnace by a workman provided with a tool consisting of a block of wood. There a sheet of glass is formed which it is necessary to anneal by making it pass successively through ovens of diminishing temperatures. The sheet is then rinsed in acidulated water and reduced to sizes required in the trade by the "cutters". It is not necessary to describe the old method of making sheet glass by the method called "in plates". This system has now been abandoned in the majority of countries having a large output.

Hand labour in making sheet glass is also tending to disappear before the advance of mechanical manufacture. The three principal automatic methods are that of the American Window Glass Society, the Belgian Fourcault method, which was the first to be developed, and the Libbey-Owens method — a variant of the Fourcault.

System of the Window Glass Society. — The glass from a tank furnace is ladled into refractory pots surmounted by a lofty powerful metal framework. From the top of this framework, concentrically to the walls of the framework and refractory pot, the essential tool of the system, called the "cold blowpipe", comes down; it is a reversed metallic cup and is turned inwards at the edges. Plunged into the mass of glass this cup fills partially and the glass chilled on coming into contact with it solidifies against the inside edges. Compressed air is brought to the interior of this cup and a regular uprising of this determines the formation of a drawn cylinder 10 to 12 metres high and 60 centimetres in diameter. These cylinders when cooled are laid mechanically on stands, where the ends are cut off by a circular wire heated electrically; the cylinders are then slit longitudinally by a diamond and carried to the flattening oven.

Fourcault's process. — Instead of the "workplaces" of a tank furnace, small tanks heated separately are employed, and to them the molten metal flows at a constant level. On this pot floats the essential tool of the system, which is a rectangular trough of refractory material of a length appropriate to the size of the sheet of glass to be made and the bottom of which has a raised longi-

tudinal slit. The width of this slit determines the thickness of the sheet. In causing the trough to sink mechanically into the molten metal a sheet of glass emerges through the slit to meet a "bait" consisting either of a metal frame or a layer of glass which attaches itself to the sheet and determines its progressive drawing by its later ascending motion. The sheet of drawn glass is guided in its vertical position by a series of asbestos rollers arranged one above the other on either side. At the top it is cut to required lengths in course of its passage. Fourcault glass does not require to be annealed. (See figs. 134 and 135.)

Libbey-Owen's process. — The general arrangement of the tanks are like those characteristic of the Fourcault process. The action of the trough is replaced by that of pairs of toothed rollers, which keep the sheet of the required size during drawing by a metal bait plunged into the molten glass. When it has reached a certain degree of height vertically the sheet is reheated until it has become so soft as to sink in a curve at right angles on to a folding cylinder from whence it is drawn mechanically.
into a long horizontal gallery which acts as a means for annealing. On leaving this flattener the sheet is cut to the desired size.

Glass Bottle Making

(French: fabrication des bouteilles; German: Glasflaschenfabriken.) Bottles, flasks, medicine bottles, etc., are made of blown glass. When done by hand, after a preliminary shaping has been effected on the "marver", a plate of polished iron, it is blown to the size wanted in a mould, generally of cast iron, which is cooled on the outside to avoid sticking. Sometimes the inside of the mould is smeared with oil. Contrary to what is the usual (tumblers, water jugs, etc.), ornamental vases, scent bottles, etc. Methods of manufacture vary a great deal: blowing of the glass in the open or in moulds, in which pressure is sometimes used; later, fashioning of the articles in the mass while still pasty by means of shears and other tools (pantiles); clipping and flattening of the edges of the glasses on grindstones; reburning of this edge with the blow-pipe; decoration of the articles by cutting, polishing and engraving.

Manufacture of Mirrors and Other Pressed Glass

(French: fabrication des glaces et des autres verres coulés; German: Spiegelglasfabriken.) The molten metal drawn mechanically from the furnaces into crucibles of large dimensions is brought by a pont roulant and poured on to a horizontal table, consisting of a thick plate of metal. Side strips regulate the thickness to be given to the glass, which is spread out by means of a cast iron roller which takes off from the lateral strips as a support. The sheets of plate glass then pass into the flattening furnaces where they are annealed and gently cooled. All that remains is to polish them and cut them to size. Similar methods serve for the manufacture of "special glasses": slab glass; wire glass; fluted, starred,
striped glass, etc. These glasses are poured on to tables the surface of which carries, for the purposes of moulding, the imprints which are to appear in relief on the glass. Certain special machinery for making this kind of glass consists essentially of two rollers, one of which is engraved and produces on the sheet, subjected to this rolling process, while still hot, the design intended.

**Mirror polishing.** — Polishing by hand is exceptional; all the work is done by very perfected machines. The mirrors, fixed on to tables of great size by cement, undergoes a preliminary process (softening, roughing down or polishing down) with the object of removing, owing to the soft quartz sand used, the roughnesses from the surface, by energetic rubbing with friction plates moved mechanically in a circular direction. The *softened* glass then passes to the "soaping", which is an operation analogous to that just described, but effected with emery powder, finer and finer in grain. Next they are polished by the same process, but the felts on the wheels, or on plates with a circular movement, are dressed this time with putty powder or very fine oxide of iron (colcothar). The process is repeated on the face originally cemented down.

**Mirror beveling.** — This is a process involving both cutting and polishing. The bevel is formed by grinding down on a very hard grindstone, turning in a horizontal plane and sprinkling with wet quartz sand. Next it is softened and polished on wheels similar to those described, but dressed with appropriate materials.

**The making of mirrors.** — The tinning of looking glasses has practically disappeared. It was done with an amalgam of a very thin sheet of tinfoil previously applied on the glass; an operation followed by the vaporisation of the excess of mercury. The silvering of mirrors is now done as follows. On to a carefully cleaned sheet of glass placed horizontally on a heated table an ammoniacal solution of silver is poured in amount sufficient to cover the surface to an even depth. The silver is precipitated by adding a reducing agent (tartaric acid, formic aldehyde, etc.); the heat of the table favours the reaction and brings about evaporation of part of the liquid, which is got rid of by decantation. The very adherent but fragile coating of silver is covered with a protective varnish.

**Engraving on mirrors.** — Mirrors are engraved by different methods: by sand blasting or by acid. By the sand blast: the mirror is covered with a thick sheet of special paper on which is cut out the design to be reproduced; in this state it is subjected to the action of compressed air carrying with it crude

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*(Photo Nels, Brussels)*
sand: the violence of the jet cuts into the glass at the points desired. By acid: according as the object is to have a brilliant etching or a mat engraving use is made of hydrofluoric acid or of an acidulated solution of fluorides of ammonium and sodium. Frosted glass is obtained by covering the sheets with a hot layer of strong glue; in drying under certain conditions the retraction of the glue tears off particles from the surface of the glass.

Cutting flint and hollow glass. — Wine glasses, table glass and similar articles are cut by a hard corundum, carborundum or sandstone wheel, etc., kept wet by a mixture of water and quartz sand. The operative presents the part of the object that he wishes to cut to the action of a vertical wheel turning at high speed; the action of the melted wax or paraffin, or covered with Jew's pitch. On this protecting layer the design to be reproduced is traced either by hand or mechanically: the action of an appropriate acid bath does the rest. The bitumen is removed by ammonia or the wax by hot water. Sometimes use is made of litho transfers gummed on to the object to be engraved with acid.

SOURCES OF DANGER

The raw materials used in the manufacture of glass are all more or less noxious, and the fact that they are in a fine state of division makes them particularly difficult to control. They exert at one time a mechanical, at another an irritating, action. Sometimes even they are toxic (lead, rarely

hands determines the depth and form of the cut article. Smoothing is done with fine emery, and polishing on leaden, wooden, and cork wheels, and on felt mops dressed with putty or similar powder.

Engraving of drinking vessels. — Glasses and other similar objects are engraved by grinding, which in this case is done on a small metal wheel some centimetres in diameter. It revolves at a high rate of speed and is dressed with emery mixed with oil. These articles are engraved also by hydrofluoric acid or fluorides. The object to be engraved, generally table glass, is either dipped into a bath of manganese, or, more rarely still, arsenic). According to Schaefer, much arsenic (30-35 kg. per day) is still used in German glass works. Analysis of the mixture used in a glass works at Saarburg showed in 100 parts: carbonate of soda and potash, 90.431 [sic]; arsenious anhydride, 1.444; manganese dioxide, 1.1125; silica, carbon and organic matters, 8.100. Mention also, for completeness' sake, should be made of nickel, antimony and chrome. These dusts have effect on the skin (eczema), on exposed mucous membranes (the eye and nose), and particularly on the respiratory tract. Lesions from chromates are rare; Gerbis, however, describes cases of ulceration and perfora-
tion of the nasal septum, which Rambousek had already found in Bohemian glass workers. Mixing quartz sand, crushed silica, lime, soda, etc., with a spade is an unhealthy operation, but this practice is common in many factories, and it cannot be denied that even when mechanical mixing is the practice risk is still very frequent. In the course of drying the mixture, the workmen may sometimes have to work in places where the temperature reaches 70°C. (Gerbis).

Melting and Annealing

The gas producers used for heating the furnaces permit the escape of carbon monoxide which often makes its way into the sheds, but it is especially in the flattening of window glass that this gas vitiates the atmosphere. The reason for this is that to carry out the manual operations necessary for flattening, the furnaces require to be kept open. Further, the incomplete combustion of the wooden utensils used in the work is also detrimental. The gas given off from the molten vitreous mass itself in the furnace ought also to be borne in mind as tending to vitiate the atmosphere. Besides carbon monoxide these gases contain, exceptionally it is true, arsenical compounds or the products of other elements (lead, silicon), which enter into the composition of glass (crystal, coloured glass). The dust also is abundant in proximity to the furnaces.

Work in front of the great heat of the fire exposes to dangers of another kind, which are extremely common, but the degree of danger differs very much in the different branches of glass making. In the manufacture of sheet glass by the hand method of making the cylinders the effect of the heat on the external skin was especially marked formerly in the manufacture of this glass in pot furnaces. The helpers who did the gathering all had the side of the face turned towards the glory hole in an erythematous and noticeably pigmented condition. Generally the high temperature which exists near the furnaces induces excessive sweating and hyperaemia of the skin with pigmentation. This action on the skin predisposes to suppurative inflammations. Burns are frequent and, as industrial stigmata and deformities, a thickening and keratinisation of the skin with the formation of obstinate ulcers between the callosities is seen. Sometimes, too, deformities of the fingers and Dupuytren's contraction particularly are found. Plate glass blowers, who work standing upright and manipulate cylinders of 20 kg., often show hypertrophy of the left arm, varicose veins, oedema of the legs, and flat feet. Chronic wryneck is much less frequently found.

In summer, heat strokes occur among those groups of workers who are subject to vertigo and fainting. During cold weather going quickly from an overheated atmosphere to one that is cold and humid predisposes to muscular and joint pains, sometimes acute, but more often chronic, and accompanied by heart complications (glass workers' rheumatism). On the other hand, some writers maintain that maladies described as "chills" (laryngitis, bronchitis, pleurisy, etc.) are not more frequent than in other trades. Abuse of cold drinks predisposes to gastric trouble.

Among the fairly frequent ocular lesions due to work in front of the furnaces and the remelting of the edges of drinking glasses are blepharitis, conjunctivitis, lesions of the cornea (xerosis), iritis (rare), early arcus senilis, and cataract (especially posterior) (see later).

Lastly, otitis and even labyrinthine haemorrhages (said to be due to straining efforts in blowing) are described; characteristic lesions of the teeth (especially of the incisors) are also described.

To this should be added the common bad habit of using the same drinking vessel and the same pipe.

Lead poisoning has been reported among the blowers of electric bulbs, the crystal glass used having a high percentage of red lead. Lead vapour is given off from the melting furnaces and bulbs as they are being fashioned, so that, at the end of blowing, the workman has run the risk of inhaling some.

Lastly, some importance must be attached to the irritation of the throat produced in glass bottle blowers from the oil which burns in the moulds from contact with the incandescent glass.
Even in the course of manufacture cuts are frequent, and causes exist which may give rise to very serious accidents. Thus falls to the bottom of the lengthening pits are nearly always fatal, because they contain too often the debris of glass coming from faulty makes. These broken pieces stick up like bayonets or daggers. Women who carry the cylinders which are not annealed, and the mirror carriers, often run risk of bad cuts. Further, cuts on the hands and forearms are numerous among glass cutters handling, perhaps carelessly, great thin sheets of glass. The necessity for tying the radial artery is fairly frequent in this last group.

Cutting, mechanical engraving and the fine grinding of glass and plate glass is generally done by a moist method. It would seem that insufficient attention has been paid to the danger from the action of the abrasives on the respiratory tract. The moist particles fall on the floor and tables, dry there, and their final dispersal into the atmosphere renders them very harmful to the lungs.

It is unnecessary to insist on the dangers from sand blasting or on the unpleasant effects of vapour of hydrofluoric acid, or ammoniacal vapours which are given off in certain workrooms for chemical engraving.

The acid liquids (fluorine, etc.) are the cause of painful ulcerations of the skin (hands), and of damage to the nails. Mention only need be made of the fumes given off in silvering chambers and amongst these of the alcoholic vapours entering into the composition of certain varnishes. Glass polishing by means of putty powder (a mixture of oxide of lead (two-thirds) and oxide of tin (one-third)) exposes the workers to the risk of lead poisoning. Moreover, in flint glass works it is fairly frequently the practice to make the red lead necessary for the mixtures on the spot.

**Statistics**

An enquiry in Germany in 1906 as to the health of glass workers, resulted in the collection of data of morbidity concerning 30,529 persons who were kept under control for a whole year, and mortality data as to 22,052 persons. The average figures per 100 workmen were 45.75 for morbidity, and 0.71 for mortality, as contrasted with 37.80 to 42.95 for morbidity, and 0.81 to 0.89 for mortality among the members of several sickness insurance societies in Berlin.

According to the German Association of Glass Bottle Workers, the sickness rate among the members was as follows (Group A, blowers; helpers; Group B, assistants, furnace stokers, boy carriers) during the years 1905-1913 and 1909-1921:

<table>
<thead>
<tr>
<th>Diseases</th>
<th>Group A</th>
<th>Group B</th>
<th>For 100 insured in the Leipzig Sickness Insurance Society</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of workmen employed during the observation period</td>
<td>69,932</td>
<td>27,968</td>
<td>—</td>
</tr>
<tr>
<td>Influenza</td>
<td>8.62</td>
<td>6.68</td>
<td>2.830</td>
</tr>
<tr>
<td>Pulmonary</td>
<td>0.69</td>
<td>0.54</td>
<td>0.770</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>0.66</td>
<td>0.60</td>
<td>0.299</td>
</tr>
<tr>
<td>Acute articular rheumatism</td>
<td>0.10</td>
<td>0.02</td>
<td>0.040</td>
</tr>
<tr>
<td>Polsonings, alcoholism</td>
<td>0.06</td>
<td>0.02</td>
<td>0.055</td>
</tr>
<tr>
<td>Tumours, diabetes</td>
<td>0.06</td>
<td>0.02</td>
<td>0.005</td>
</tr>
<tr>
<td>Diseases of the circulatory system</td>
<td>1.25</td>
<td>0.80</td>
<td>1.010</td>
</tr>
<tr>
<td>Rheumatism, gout</td>
<td>6.83</td>
<td>3.49</td>
<td>3.630</td>
</tr>
<tr>
<td>Diseases of the eyes</td>
<td>0.78</td>
<td>0.51</td>
<td>0.100</td>
</tr>
<tr>
<td>Cataract</td>
<td>0.28</td>
<td>0.10</td>
<td>0.521</td>
</tr>
<tr>
<td>Other ocular diseases</td>
<td>1.89</td>
<td>1.13</td>
<td>0.843</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>0.80</td>
<td>0.74</td>
<td>0.387</td>
</tr>
<tr>
<td>Pulmonary</td>
<td>0.19</td>
<td>0.15</td>
<td>0.380</td>
</tr>
<tr>
<td>Emphysema</td>
<td>0.19</td>
<td>0.15</td>
<td>0.380</td>
</tr>
<tr>
<td>Other respiratory diseases</td>
<td>11.71</td>
<td>8.22</td>
<td>4.860</td>
</tr>
<tr>
<td>Diseases of the digestive tract</td>
<td>13.55</td>
<td>7.27</td>
<td>6.090</td>
</tr>
<tr>
<td>External lesions</td>
<td>13.11</td>
<td>15.23</td>
<td>9.390</td>
</tr>
<tr>
<td>Total</td>
<td>58.86</td>
<td>58.92</td>
<td>39.510</td>
</tr>
</tbody>
</table>

The number of deaths during the periods 1907-1913 and 1919-1923 among the blowers, the helpers, the assistants, etc. (a total of 89,650), was 496 (5.52 per cent.). The causes were: influenza, 15 times; bronchitis, 3; pneumonia, 75; pulmonary catarrh, 35; tuberculosis, 78; other tubercular diseases, 8; various, 251.

The age at death, compared with the figures of the Leipzig Sickness Fund, was (per 100 deaths):

<table>
<thead>
<tr>
<th>Leipzig Sickness Fund</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 56 years</td>
</tr>
<tr>
<td>Between 50-54</td>
</tr>
<tr>
<td>40-49</td>
</tr>
<tr>
<td>35-39</td>
</tr>
</tbody>
</table>

According to Gerbis, who examined 3,500 German glass workers, the average age was 43.95. He found also that the working capacity of the glass bottle blower was ten years longer than that of the sheet glass blower. The latter gave up the work on the average at fifty years of age and took up less trying work in the same factory.

The frequency of tuberculosis among the polishers was, according to Putegnat (1881), 40 per cent. and according to
Anacker (1882) 31.2. Lode and Schwieland gave rates still higher (75). The improvement in technique and better living among the workers have much improved their conditions.

An enquiry made in Bavaria (1906) brought out that in the Northern districts the average morbidity over a period of ten years for all glass workers was 57, with 830 sick days per 100 workers. The conditions of workers in factories were better than those of workers employed in workshops or at home. Wittgen (1913) collected a great number of data among workers in German glass bottle factories. He found a sickness rate of 78.3 per cent, as against a rate of 187 for Austrian glass workers (Hauck). Whilst in Germany external lesions numbered 14.5, digestive maladies 1.4, and tuberculosis 0.74 per 100 cases of sickness annually, in Austria the external lesions numbered 25.7 and digestive maladies 60.7.

The data given by Hauck in 1910 allow conclusions to be drawn as to the frequency of certain maladies among German glass blowers and helpers (rates per 1,000 workers):

<table>
<thead>
<tr>
<th>Diseases</th>
<th>Blowlers</th>
<th>Assistants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subcutaneous cellulitis</td>
<td>193.5</td>
<td>50.6</td>
</tr>
<tr>
<td>Pulmonary tuberculosis</td>
<td>103.8</td>
<td>11.7</td>
</tr>
<tr>
<td>Acute and chronic</td>
<td>105.0</td>
<td>11.7</td>
</tr>
<tr>
<td>Rheumatism</td>
<td>100.0</td>
<td>11.7</td>
</tr>
<tr>
<td>Acute and chronic</td>
<td>106.0</td>
<td>11.7</td>
</tr>
<tr>
<td>Bronchitis</td>
<td>106.0</td>
<td>11.7</td>
</tr>
<tr>
<td>Diseases of the teeth</td>
<td>106.0</td>
<td>11.7</td>
</tr>
<tr>
<td>Diseases of the stomach</td>
<td>106.0</td>
<td>11.7</td>
</tr>
<tr>
<td>Wounds</td>
<td>106.0</td>
<td>11.7</td>
</tr>
<tr>
<td>Burns</td>
<td>106.0</td>
<td>11.7</td>
</tr>
</tbody>
</table>

The cases of sickness numbered 750.1 (deaths, 9.6) per 1,000 workers in flint glass works; 1,870.3 (deaths, 8.5) for bottle factories; 996.1 (deaths, 6.5) for sheet glass factories.

Statistics prepared by the Central Federation of male and female glass workers in Germany for the period 1911-1923, numbering 382,993 members, gave 2,164 deaths (5.67 per 1,000 members), who were thus distributed by age groups:

<table>
<thead>
<tr>
<th>Age at death</th>
<th>Blowlers</th>
<th>Assistants</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-20 years</td>
<td>207</td>
<td>51-70</td>
</tr>
<tr>
<td>30-39 years</td>
<td>206</td>
<td>32-50</td>
</tr>
<tr>
<td>40-49 years</td>
<td>206</td>
<td>42-60</td>
</tr>
<tr>
<td>50-59 years</td>
<td>206</td>
<td>52-70</td>
</tr>
<tr>
<td>60-65 years</td>
<td>206</td>
<td>62-70</td>
</tr>
</tbody>
</table>

By causes of death: circulatory diseases, 129; respiratory diseases, 752; diseases of the digestive tract, 163; diseases of the throat, 36; diseases of the bladder, 21; diseases of the kidneys, 80; cerebral haemorrhage, 113; influenza, 132; accidents, 100; suicide, 67; various, 445.

So far as accidents due to work are concerned, the Professional Association of German Glass Workers gives the following statistics:

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of factories</th>
<th>Number of workers employed</th>
<th>Number of reported accidents</th>
<th>Number of reported accidents for the first time</th>
<th>Number of fatal cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900</td>
<td>829</td>
<td>74,004</td>
<td>1,596</td>
<td>568</td>
<td>10</td>
</tr>
<tr>
<td>1905</td>
<td>908</td>
<td>77,948</td>
<td>2,359</td>
<td>563</td>
<td>11</td>
</tr>
<tr>
<td>1910</td>
<td>1,078</td>
<td>84,831</td>
<td>2,670</td>
<td>579</td>
<td>8</td>
</tr>
<tr>
<td>1914</td>
<td>1,110</td>
<td>93,069</td>
<td>9,080</td>
<td>938</td>
<td>13</td>
</tr>
</tbody>
</table>

Statistics for the period 1841-1908 drawn up by an American mutual insurance society showed an average duration of life of 41.4 for 901 deaths. The causes of death were (per 100 deaths) as follows: tuberculosis, 31.85; pneumonia, 7.77; chronic nephritis, 5.66; diseases of the liver, 2.77; paralysis and apoplexy, 4.55; accidents, 9.53; suicides, 1.88; all other causes, 26.45.

The Prudential Insurance Company (1914-1918) published the following statistics on the incidence of tuberculosis compared with that of the male population of the United States distributed in age groups:

<table>
<thead>
<tr>
<th>Age at death</th>
<th>Mortality of glass blowers</th>
<th>Relative rates of mortality from pulmonary tuberculosis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All causes</td>
<td>Pulmonary tuberculosis</td>
</tr>
<tr>
<td>15-24 years</td>
<td>136</td>
<td>36</td>
</tr>
<tr>
<td>25-34 years</td>
<td>217</td>
<td>82</td>
</tr>
<tr>
<td>35-44 years</td>
<td>148</td>
<td>59</td>
</tr>
<tr>
<td>45-54 years</td>
<td>177</td>
<td>77</td>
</tr>
<tr>
<td>55-64 years</td>
<td>125</td>
<td>14</td>
</tr>
<tr>
<td>65 and over</td>
<td>75</td>
<td>3</td>
</tr>
</tbody>
</table>

Among 111 deaths Gerbis found that 24 were due to tuberculosis.

The cases of lead poisoning reported to the Factory Department in Great Britain from glass polishing numbered 7 in 1900.
GLASS INDUSTRY

11 (3 deaths) in 1901, 8 (2 deaths) in 1902, an average of 2 from 1903 to 1905, an average of 4 (1 death) from 1906 to 1908, 3 (1 death) on an average from 1909 to 1911, 2 (1 death) on an average from 1912 to 1914, 1 in 1918, 2 in 1921. Statistics as to this cause are not given in the reports for later years.

The Glass Workers' Federation of Czechoslovakia in their report for 1924 give the following table of the deaths of members drawn up with every care:

<table>
<thead>
<tr>
<th>Occupational category</th>
<th>1912-1914</th>
<th>1923</th>
<th>1924</th>
<th>Number of deaths</th>
<th>Average age</th>
<th>Number of deaths</th>
<th>Average age</th>
<th>Number of deaths</th>
<th>Average age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skilled workers</td>
<td>30</td>
<td>46.8</td>
<td>42</td>
<td>42.9</td>
<td>33</td>
<td>35.5</td>
<td>34</td>
<td>34.4</td>
<td></td>
</tr>
<tr>
<td>Glass polishers</td>
<td>30</td>
<td>44.4</td>
<td>27</td>
<td>45.9</td>
<td>25</td>
<td>35</td>
<td>25</td>
<td>34.4</td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td>5</td>
<td>33.4</td>
<td>22</td>
<td>48.0</td>
<td>27</td>
<td>35</td>
<td>25</td>
<td>34.4</td>
<td></td>
</tr>
<tr>
<td>Other workers</td>
<td>14</td>
<td>57.9</td>
<td>27</td>
<td>46.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>91</td>
<td>45.5</td>
<td>118</td>
<td>45.3</td>
<td>89</td>
<td>34.1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Among 926 glass workers subjected to medical examination in 1926, 229 (25.16 per cent.) were found with eye affections, viz. cataract (early), 3.79; cataract (advanced), 3.98; presbyopia, 5.29; myopia, 3.89; conjunctivitis, 2.15; weakness of sight and blindness, 5.95.

The average age of the deceased glass workers had sensibly improved for it fell from 47.1 in 1925 to 45.6 in 1924 and was 51.2 in 1926. In that year the average age of glass workers was 55.6, that of polishers 52.6 (general average 51.2).

In the opinion of the Federation the raising of the average age during the last five years is proof of the effect in improving the health of the workers of the eight-hour day and the propaganda on health education.

Burns, usually slight, are very frequent, on the arms and legs and particularly on the feet. Glass debris, too, is also a frequent cause of damage to the feet (especially in summer time when the workman is not wearing shoes).

In 1912, 135 severe cases of burns involving 804 days of incapacity, and about 400 slight cases not involving incapacity, were reported in one year in a German glass works employing 1,600-1,700 workers.

PATHOLOGY

Among the cutaneous lesions, erythema, sometimes erysipelatous in character, with oedema of the eyelids and nose, due to the heat, must be borne in mind (Mazzi and Sgai): also an eczematous form, known under the name of watery itch, among the polishers, attributable to the mechanical and chemical action of the gritty powder.

Cutaneous lesions are also described on the palm of the hands (metacarpophalangeal joints) attributed by some writers to the grease (a mixture of wood charcoal, pitch, colophony or sometimes wax, etc.) which contains resin believed by Stein to be the real cause.

On the external part of the conjunctiva of the corner of the eye the heat rays cause spots of xerosis which Ewetzky (1890) found in 31 out of 70 glass blowers examined. Damage to the eyes and neighbouring parts due to glass splinters is frequent.

An occupational deformity of the cheeks has been observed for a long time, due to exaggerated and repeated distension of the cheeks while blowing, which causes the pressure of air breathed to vary from 6 to 8 mm. of mercury up to 150 mm. This excessive pressure provokes a distension of the soft parts of the face and, eventually, paralysis of the corresponding muscles. The same cause accounts for the swelling of the parotids by dilatation of Stenon's duct with annoying consequence resulting in inflammation and infection of these organs. Scheier (1921) studied closely the damage to the teeth and mouth of blowers. H. Reichert (1921) also examined 123 workmen with the same object: 90 per cent. of the blowers showed a more or less marked change in the buccal mucous membrane (cheek), in the form of ulceration or very deep cracks. Pneumatocele of Stenon's duct has been reported by Reichert in 12 per cent. of those examined by him; in 5 per cent. it was on the right side, in 3 on the left, and in 7 on both sides.

The mouthpiece of the blowpipe, owing to the rotating movement the blower gives to it, acts really like a saw on the teeth. The lesions found are therefore of a mechanical nature, and it is the rule to find in the blower's denture a hole the diameter of which corresponds exactly with that of the mouthpiece. This alteration was found in 50 per cent. of 123 blowers examined, and in 97 per cent. of a group of old men. The mechanical
injury is at the same time complicated by a chemical and bacterial action, which excites the well-known picture of dental caries among the glass blowers. As consequences of such a lesion are the effects on the looks, the voice and digestion.

The fairly abundant data relating to cataract among glass workers, resulting from the different investigations carried out, may be presented in the following table:

<table>
<thead>
<tr>
<th>Authors</th>
<th>Years</th>
<th>Number of workers examined</th>
<th>Cases (per 100 workers) of cataract found in workers aged less than 40 years</th>
<th>Workers aged from 41 to 50 years</th>
<th>Workers aged from 51 to 60 years</th>
<th>Number of workers examined</th>
<th>Cases (per 100 workers) of cataract found in workers aged over 60 years</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meyhöfer</td>
<td>1890</td>
<td>566</td>
<td>9.5</td>
<td>26.5</td>
<td>513</td>
<td>135</td>
<td>0.9</td>
<td>83.5</td>
</tr>
<tr>
<td>Rohlinger</td>
<td>1890</td>
<td>287</td>
<td>3.35</td>
<td>19.23</td>
<td>373</td>
<td>157</td>
<td>0.6</td>
<td>99.4</td>
</tr>
<tr>
<td>Legge</td>
<td>1890</td>
<td>578</td>
<td>10.6</td>
<td>29.9</td>
<td>401</td>
<td>131</td>
<td>0.7</td>
<td>99.3</td>
</tr>
<tr>
<td>Huber</td>
<td>1920</td>
<td>468</td>
<td>10.0</td>
<td>30.0</td>
<td>413</td>
<td>131</td>
<td>0.7</td>
<td>99.3</td>
</tr>
<tr>
<td>Wick</td>
<td>1925</td>
<td>32</td>
<td>2.8</td>
<td>37.3</td>
<td>32</td>
<td>10</td>
<td>0.3</td>
<td>97.7</td>
</tr>
<tr>
<td>Kolena</td>
<td>1925</td>
<td>425</td>
<td>1.25</td>
<td>11.9</td>
<td>48</td>
<td>14</td>
<td>0.3</td>
<td>97.7</td>
</tr>
</tbody>
</table>

Meyhöfer found cataract present in 89 (11.9 per cent.). The 42 cases found among the 442 workmen aged less than forty years were distributed thus in the following age groups: up to twenty years of age, 6 cases; from twenty-one to thirty years, 20; from thirty-one to forty, 16 cases. Seventeen cases (26.5 per cent.) were found among 64 workmen over forty years of age. Rohlinger's enquiry brought out the fact that the glass bottle makers were particularly hit, because 31.25 per cent. of the workmen received compensation for cataract, as compared with 26.5 per cent. among 185 members of a glass bottle trade union. The average of invalidity was fifty-six years. The data he collected from his examination of the eyes of 513 glass blowers may be classified thus:

<table>
<thead>
<tr>
<th>Workers aged from 30 to 40 years</th>
<th>Workers aged from 41 to 50</th>
<th>Workers aged from 51 to 60 and over</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number examined</td>
<td>Cases of cataract</td>
<td>Per. cent.</td>
<td>Number examined</td>
</tr>
<tr>
<td>Sheet glass</td>
<td>Blowers</td>
<td>48</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Gatherers</td>
<td>90</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Flatteners</td>
<td>78</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td>216</td>
<td>24</td>
<td>11.1</td>
</tr>
<tr>
<td>Glass bottles</td>
<td>Finisters</td>
<td>88</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Blowers</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Gatherers</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>102</td>
<td>9</td>
<td>8.8</td>
</tr>
<tr>
<td>Pressed glass</td>
<td>Finisters</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Gatherers</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>11</td>
<td>2</td>
<td>18.2</td>
</tr>
<tr>
<td>Total</td>
<td>229</td>
<td>35</td>
<td>15.6</td>
</tr>
</tbody>
</table>

The different forms of cataract found among these 513 glass workers examined by Legge were as follows:

- **Right eye**
  - Cataract extracted
  - Cataract so mature that its nature could not be determined
  - Posterior cortical cataract
  - Commencing posterior cortical cataract
  - Minute posterior polar opacity
  - Posterior cortical opacities (not in central area), radii, striae
  - Peripheral striae, radii and sectors
  - Other opacities
  - General dulness of lens

- **Left eye**
  - Cataract extracted
  - Cataract so mature that its nature could not be determined
  - Posterior cortical cataract
  - Commencing posterior cortical cataract

<table>
<thead>
<tr>
<th>Right eye</th>
<th>Left eye</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minute posterior polar opacity</td>
<td>5</td>
</tr>
<tr>
<td>Posterior cortical opacities (not in central area), radii, striae</td>
<td>4</td>
</tr>
<tr>
<td>Peripheral striae, radii and sectors</td>
<td>14</td>
</tr>
<tr>
<td>Other opacities</td>
<td>5</td>
</tr>
<tr>
<td>General dulness of lens</td>
<td>7</td>
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</table>

<table>
<thead>
<tr>
<th>Right eye</th>
<th>Left eye</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>64</td>
</tr>
</tbody>
</table>
Wick, in 1922, examined 158 blowers in two glass bottle works and in one group, with the pupil dilated, found 11.6 per cent. of cases of cataract; in another using protective screens of deep blue glass, only 1.9 per cent. Among 66 blowers, cataract was present in 44.9 per cent. and in 92, who were only employed occasionally in blowing, 19.5 times. Kubik (1923) among 63 blowers in two glass bottle works, aged from eighteen to sixty-one years, found 3 instances of detachment of the posterior lamellar zone, described for the first time by Elschnig. According to this expert, under the action of heat, striae occur in this zone, and these again, under the action of endocularity tension, assume the form of a straight line and is frequently a posterior cortical cataract, that is, it is situated in the part least exposed to aqueous humour of which the concentration is said to be altered. This is why, in addition to other reasons, experts think now that cataract in these workers is due to the action of ultra-violet rays (Cramer, Schanz, Stockhansen), or to caloric rays (Hirschherg, Hartridge, Hill, etc.), which, absorbed by the lens, bring about very fine changes in its structure. It might be admitted too that the caloric rays injure the lens directly or indirectly by altering its nutrition; in this case the iris would intercept these rays and so bring about a lesion of the secretory activity of the ciliary bodies and a change in the aqueous humour. Van der Hoeve believes that the ultra-violet rays injure the ciliary bodies and nutrition of the lens in such a way that this is directly affected by the ultra-red rays. A. Vogt, of Zurich, has been able in a few minutes to bring about a cataract in rabbits by ultra-red rays after having eliminated the caloric rays.

William Crookes also studied the subject from the physical side and particularly the effect of different metallic oxides added to the elements constituting glass, with the object of eliminating the invisible ultra-violet and ultra-red rays from the spectrum, that is, the rays from the molten glass, which are believed to be the cause of the damage. This authority did not find X-rays in the rays from molten incandescent glass, but he found on the

<table>
<thead>
<tr>
<th>Age group (years)</th>
<th>Number of workers examined</th>
<th>Cataract</th>
<th>Total</th>
<th>Per cent.</th>
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<tbody>
<tr>
<td>30-34</td>
<td>37</td>
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<td>18.20</td>
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<td>40-44</td>
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<td>55-59</td>
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<td>50.00</td>
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<tr>
<td>70-75</td>
<td>1</td>
<td>2</td>
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<td>50.00</td>
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<tr>
<td>76-80</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>50.00</td>
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<td>81-85</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>50.00</td>
</tr>
</tbody>
</table>
other hand heat rays almost more abundant than the ultra-violet. He concluded that it was the heat rays and not the light rays which were the cause of the cataract. At the same time there is no doubt that ultra-violet rays are harmful for the eye.

Good glasses should absorb the rays of wave-length greater than 7,200 and eliminate the obscure calorific rays: it should be impenetrable to rays of wave-length less than 3,550 in order to eliminate the rays chemically more active. Crookes succeeded in preparing glasses which absorb more than 90 per cent. of the heat rays and are impenetrable to ultra-violet rays. They are suf-

ciently pale in shade to permit of wearing them without discomfort. At the same time these three desiderata cannot be combined in a single type of glass. Crookes gives the formula for preparing these types of glasses and says of them that they hardly obstruct the passage of light and allow easily of the recognition of colours. Authorities lay stress on the danger of glass dust, especially to those engaged in mixing the raw materials, polishing and cutting glass. Respiratory diseases are frequent, and particularly incidence of tuberculosis is rather high; but its had a mortality rate of 47.4 per cent. from respiratory diseases and of 34.5 from tuberculosis. The presence of lead compounds in the dust increased the figures. For the period 1907-1912 among 220 deaths of glass cutters tuberculosis accounted for 36.4.

It has for long been admitted that glass blowers suffer from pulmonary emphysema which Prettin and Liebkind found present only in 5 cases among 230 glass blowers employed for at least ten years.

Glass workers succumb occasionally to peripheral nervous maladies. Thus

Fig. 135. — Tank furnace for melting. (Glass works at Gilly, Belgium.)
Teleky in 1923 found a polisher who rested his forearm on the table suffering from ulnar paralysis. Bursitis over the elbow has also been reported quite often. Manipulation of the heavy blowpipe and vitreous mass raised causes a fatigue and strain of the arm muscles and wrist as well as acute and chronic teno-synovitis. Mazzi and Sgai have found among cells and small number of polychromatophils either to the action of lead dust in the air or of silica dust. The presence of silica in the urine has convinced Mazzi that an absorption takes place of a compound of silicon (tetrachloride or other volatile compounds of silicon).

A fatal case of poisoning from selenium occurred in a German glass bottle works in 1926 where sodium selenide was used as a decolorising agent.

Cases of lead poisoning are more numerous and are due to the use of putty powder for polishing glass, a powder which contains a high proportion of lead oxide; or to the use of red lead in certain types of incandescent electric light bulbs, etc.

Fig. 136. — Tank furnace for drawing seen in detail.
(Glass works at Gilly, Belgium.)
Thus, for example, in Great Britain between 1900 and 1909, 48 cases of lead poisoning caused by putty powder were reported; in Vienna, in 1920, a small epidemic of lead poisoning occurred in a factory where red lead was used in the manufacture of electric bulbs, whilst from other glass works 80 cases were reported. Enquiry showed a high proportion of lead in the air of the workroom due to escape of lead fumes from the furnace owing to faulty ventilation. The vitreous mass gathered by the blowpipe also gave off lead fume and the lead contaminated air in the article blown, in the inside of which 0.10 grm. of lead was found to have been inhaled through the blowpipe. Similar cases (a dozen in recent years) were reported to the Chief Inspector of Factories in Great Britain.

Cases of extra-genital syphilis among glass workers were described at Rive de Gier in 1862 (20 cases) by Viennois; others at Montluçon in 1868-69 (30 cases) by Dechaux. During the period 1858-72, 82 cases of syphilis among glass workers were treated in the Antiquaille hospital of Lyons. In Austria, Sigmund reported 4 cases. Heiberg in Denmark 9 cases; Gibert, a certain number of cases in Belgium, etc.

A report on the subject was presented to the International Congress of Medicine in Paris, 1876. In 1896 Eysel in his thesis described 11 cases of occupational syphilis among these workmen; other cases have been described by Brosing in 1914. In 1908, a case of syphilis was reported for the first time in Milan, and the enquiry which immediately followed revealed 7 other cases among the 233 glass workers examined. In the course of the same year 10 cases of extra-genital syphilis had been collected. This is the reason why the city of Milan prescribed certain regulations which have had an excellent effect. Indeed, since 1908 no further cases have occurred, and the cases found were all recognised immediately, and no further source of contagion was found (see later). In 1925 Jacoby, among 17 glass blowers examined, found 7 with syphilitic ulceration (see also article “Syphilis”).

**Hygiene**

The main principle of prophylaxis in the grinding and mixing of the raw
materials is the substitution of mechanical methods for hand labour. It is necessary, however, in this case to ensure absolute airtightness of the apparatus for grinding, mixing and charging, and to apply effective local exhaust ventilation. Good general ventilation should also be arranged so as to make it unnecessary to wear respirators and goggles except for occasional and temporary reasons. It should be unnecessary to insist on the importance of suitable and efficient gas producers, except that it is unfortunately a very common fault in the glass industry to find the sheds for the furnaces inefficiently isolated from the producers with the result that they are frequently fouled by escapes from them. The doors and other openings of the furnaces ought to be provided with airtight fastenings to prevent the escape of gases.

A general ventilation of the work sheds is indispensable both to diminish the objectionable features which have been described and to remedy the high temperature which is liable to prevail in them. In this connection it is useful to remember the benefit derived from proper isolation of the furnaces and heat recuperators. Use of protective appliances and especially of fire obscuring screens should be emphasised. In some works electric fans volve gazing at incandescent substances in the course of work should be replaced by automatic methods; as an example mention should be made of the services rendered in the manufacture of glass bottles by the automatic machines with a sidereal movement which have superseded the old arch for reburning the edges of the glass.

If the glass in the goggles or screens absorbed rays of a wave length above 7,200 the frequency of cataract would be much diminished. Experts have proposed different types of glasses. Thus Vogt and Meyer suggest glass rich in protoxide of iron ("Robonglass"); Vogt, of Zurich, has had
made by Zeiss protective glasses against the ultra-red rays, which are not however worn with comfort by the men. These men do not like wearing glasses because they do not recognise the danger and are unfortunately not forced to take the necessary precautions until it is too late. Further, the steam and moisture from excessive sweating condense on the glass and disturb vision. It is true that a layer of a special soap applied by means of a paint brush to the glass can obviate this danger. But the workmen prefer to use a screen that they can hold in front of their eyes by a support between their teeth, when they work before the furnaces, and which they keep suspended by means of a string.

The flooring of the sheds should be well maintained, and the existence of dangerous projections should not be permitted and accumulations of debris avoided. The great danger of falling into places where it is almost impossible to avoid the presence of glass debris should always be borne in mind. In this connection an old Belgian Royal Decree required trellis over the lengthening pits. This trellis was made by intercrossing iron plates, leaving between them however, sufficient space for the fragments of a cylinder accidentally broken in the course of manufacture to pass through. On the other hand, the spaces were not wide enough to allow a man to fall through. They were arranged above the floor of the pits, the whole surface of which they covered. This means of protection it would seem has not entirely fulfilled the expectations of those who suggested it because it has been more or less abandoned. An excellent measure which is extending is the mechanical transport of the cylinders.

Handling the sheets of glass during hand transport requires certain precautions; cheap means exist by which they can be carried consisting essentially of large straps with two handles and a light wooden lath support for the glass. Such an arrangement is very useful in case of accidental breakage. Much thought has been given to counteract contamination from the blowpipe used in common. A blowpipe for each worker is impracticable in certain of the processes of manufacture.

Again, for a long time effort was concentrated on the form to be given to individual mouthpieces and numerous attempts have been made to adapt them to professional requirements. All efforts having failed, other measures have been tried: medical examination of the personnel before commencing employment and subsequently at periodical intervals; suspension of suspected cases, prohibition of the use in common of drinking vessels and pipes, etc. All these measures are but insufficient palliatives where they are not followed up by the workmen themselves. However, it may be truly said that of late years, armed with more knowledge, the workmen have constituted themselves a sort of sanitary police very effective for mutual protection. This step enables them to exercise control especially over the newly employed, and to refuse to accept into their squad persons whose condition they view with suspicion.

Some remarks are necessary on the subject of the risks from the blowpipe and especially of syphilis. As is well known, the spirochaele which is the cause of this formidable malady does not survive for any length of time outside the body. It follows that even in the case of common use of the blowpipe it is necessary, to enable transmission of the infection to take place, that contact with the mucous membrane of the receiver should follow very nearly that of the donor. Generally this necessary condition is only realised in the manufacture of articles of large dimensions and more especially in that of the cylinders for window glass.

Glass blowers (e.g. in Belgium) supply drink for their two helpers. This is placed in a vessel which is used by all three persons who drink from the same neck. Each worker should be compelled to supply his own drinking utensil.

In bottle factories and in flint and hollow glass manufacture compressed air and blowing effected by machinery is a notable improvement from a sanitary point of view. Not only is this the case in regard to the prevention of syphilis and other infectious diseases but also in avoiding the ill effects arising from blowing to the mouth itself.

In some small factories a very simple apparatus for mechanical blowing is that invented by Klingley and Ambrogio d’Asti (Italy), which has been used for many years past. It consists of a small compressor driven by an electric motor which compresses the air in a reservoir to 3 atmospheres, and by a reducing valve reduces the pressure to half an atmosphere. The air thus passes into a pipe of small diameter, placed at a height of 4 metres above the floor of the workroom. Rubber
GLASS INDUSTRY

piping brings the air from the pipe to the blowpipe.

The apparatus weighs 800 grm., and a pressure of 60 grm. is sufficient to make a bottle or demijohn.

The reducing valve is opened by slight pressure from the chin and even from the rim of the cap or from the cheek.

It is in the manufacture of sheet glass that modern mechanical progress constitutes a real revolution in sanitary conditions. So far as transmission of occupational diseases is concerned the progress has obviously been radical, but in other respects also; diminution in the number of workmen exposed, suppression of arduous work in an overheated atmosphere close to large openings of furnaces; substitution for this frightful drudgery of airless work by the use of protective apparatus of safety which extends to the constant employment of screens.

The requirements too of effective ventilation become very simple.

In the later operations of cutting and polishing, injuries from dusts are in great part avoidable by constant cleanliness — frequent cleaning of workplaces and tables, wearing special clothing for working in and ridding them regularly of the dust which collects on them. Good locally applied exhaust ventilation permits of the effective removal of fume or gas in etching with acid, and similar means or the wearing of perfected breathing apparatus offers protection against injury caused by sand-blasting operations.

The danger of poisoning from the use of putty powder which contains a considerable part of lead can be removed by substituting, as is now possible, a putty powder practically harmless thanks to a formula in which there is no lead present (metastannic acid, etc.).

Thus, for example, in Belgium, Ad. Lecrenier, technical director of the Val Saint Lambert glass works, in 1922 published the composition of non-lead putty powder used at Val Saint Lambert since 1909: stannic oxide (SnO₂), obtained by calcining metastannic acid, 40 parts; metastannic acid obtained by the action of nitric acid on pure tin, then washed and dried at 110°, 26 parts: a mixture of sulphide of zinc and barium sulphate obtained by double decomposition of zinc sulphate and barium sulphide (lithopone), 34 parts. Use of this putty powder has prevented the faintest trace of lead poisoning among the 1,200 workpeople in the cutting shops.

Finally, it should be recalled that some glass works (in Great Britain for example) possess sickness assurance societies of the highest order.

The second Congress of the Italian Corporation of Glass Workers (Empoli, 25 July 1925) passed the following resolution:

1. Hours of work for workmen handling hot glass should be reduced by one half hour daily and by one hour during the summer months (June, July and August).

2. Persons under 14 years of age should be prohibited from work in glass factories and persons under 18 from glass blowing. Women and girls should not be permitted to manipulate hot glass.

3. Factories should satisfy the requirements of hygiene and be provided with protective appliances for every kind of work. In this connection:

(a) installation of furnaces in confined and ill-ventilated premises should be prohibited; installation of ventilating appliances and fans for the removal of dust and fumes should be compulsory;

(b) a constant supply of drinking water should be provided in the works; the pipes for the water coming from outside should be used for cooling the apparatus. In the winter months the water to be used in working the material should be warmed;

(c) machinery and dangerous apparatus should be securely fenced;

(d) cloakrooms, dining rooms and bath-rooms should be maintained in good condition.

4. All glass works ought to adopt mechanical methods to obviate the necessity of blowing by the mouth.

5. The weekly rest from work should be thirty-six hours for "pot" furnaces and twenty-four for tank furnaces.

In the recent enlargement of the work in the manufacture of glass the necessary stoppages for repairs in the factories should be made in summer.

The International Congress of the Federation of Glass Workers (held in Paris, December 1927) adopted, among others, the following resolutions:

(d) The International Congress of Glass Workers, assembled in Paris, is of opinion that tuberculosis and cataract in glass workers should be regarded as industrial accidents and be treated as such for compensation purposes.

The Congress should be demanded in all the countries legal regulation of accident compensation for the workers, in accordance with the Convention adopted at the Seventh International Labour Conference, Geneva, 1925, relative to occupational diseases.

(e) From the point of view of hygiene, the factories should be run in such a manner that the health of the persons employed should not be exposed to any danger.
LEGISLATION

Women are prohibited from employment in grinding and sieving of the raw materials, from dry polishing, glass cutting and decoration in relief, in Argentina, France and the Netherlands; in workrooms where poisonous materials are used and from blowing in glass works in Argentina, from furnace work and carrying in Switzerland; from grinding the raw materials and all etching by means of hydrofluoric acid and sand blasting in Germany. Young persons of less than sixteen years of age are excluded from workrooms in which mixing, grinding, and etching by acid is done; those under fourteen from workrooms in which cutting is done in Belgium; lads of less than fourteen and girls less than eighteen are prohibited from employment in dry polishing; young persons of less than sixteen are prohibited from blowing, glass cutting and etching with acid in Greece; young persons of less than eighteen years from furnace work and carrying in Switzerland; from grinding and other processes giving rise to dust in Germany; the employment of young persons of sixteen years is permitted, under certain conditions (Decree of 10 July 1922) in Denmark; boys of less than sixteen years and girls of less than eighteen are prohibited from blowing, glass cutting and etching with acid in Greece; young persons of less than eighteen years from glass trimming and in departments of all glass works in which much dust is created in France: children of less than ten years are prohibited from employment in glass cutting and etching by acid in Greece; young persons of less than fourteen years and women of less than twenty-one from grinding the raw materials, blowing, cleaning and demolition of furnaces, etching by acid or sandblast, and from glass polishing in Italy; young persons of less than fourteen from work in glass factories in Norway; the protection of young persons and children in the Netherlands is controlled by the Royal Decree of 10 August 1900 (glass cutting and polishing by means of putty powder containing lead, stained glass works, etc.: sections 27, 33, 34, etc.). For children under fourteen years see also the Act of 1922.

Special legislation affecting glass factories, etc., is not very abundant. In Germany an Order of the Chancellor, dated 5 March 1902, laid down measures for the protection of children and of women; an Order of the President of Police in Berlin dated 27 September 1911, deals with the polishing of glass. A further Order of the Chancellor on the work of women and young persons is dated 9 March 1913. The occupational association of glass workers in 1915 (July) drew up very stringent regulations for the prevention of accidents in the glass industry.

In France the Decree of 1 October 1913 deals with glass blowing by the mouth (requiring medical examination at the expense of the occupier, special register, disinfection of the blowing pipe, then used in common by the whole shift), and that of the same date with the prevention of lead poisoning (which applies also to flint glass works).

In Great Britain Regulations dated 18 December 1908 deal with enamelling of glass (see that article); a Welfare Order of 3 March 1921 deals with the protection of workers engaged in glass bevelling and processes incidental thereto (overalls, protection against splashing, dry processes, personal hygiene, etc.); that of 15 May 1918 deals with the protection of workers engaged in the manufacture of glass bottles and pressed glass articles (with the same provisions as the preceding).

In Italy the Communal Regulations of Milan (1908) provide for a medical examination on commencing employment and subsequent weekly examination by an appointed physician. In France all mouthpieces of the blowing pipe, provision of a bottle and drinking vessel for each worker, notification of cases of syphilis and open tuberculosis.

In Portugal an Act dated 28 March 1906 requires the use for each person of a special mouthpiece for the blowing pipe.

In Yugoslavia, glass blowing is dealt with in sections 154-159 of the Regulations for hygiene and safety of 25 October 1921; prohibition of the use of common blowing pipe without a medical certificate that the workman is free from contagious infections; this certificate must be renewed every fortnight (in factories) and whenever the workman returns to work after an illness (in other processes); the keeping of a health register. In work carried out by a team: disinfection of the mouthpiece when the shift is over; each blower using his own blowing pipe to have it specially marked and to have a place under lock and key to keep it in; young persons of less than sixteen years of age and women in general to be excluded from the work of melting and blowing. In the Saar Basin the League of Nations has prescribed Regulations No. 485, dated 18 July 1923, on the employment of women and young persons in glass works, flint glass, etc., in cutting and use of acid and the sandblast in engraving.

In Mexico the State of Jalisco, in the Factory Act of 13 August 1923, lays down working rules for glass works (section 215).

Glass work formed the subject of discussion at the International Labour Conference of 1924 (Geneva). The discussion was on the weekly twenty-four hour rest in glass works with tank furnaces (see the reports published by the International Labour Office).

Obligatory notification is required in the Netherlands of pulmonary affections due to acid etching and sand blasting, arsenic poisoning, eczema, dermatitis, subcutaneous cellulitis, and cataract among glass workers, and of bursting over the elbow and pulmonary affections among workmen engaged in glass polishing.

Compensation for cataract among glass workers is provided for in Germany, Great Britain, Minnesota, the State of New York, and in Russia (where it is also compulsorily notifiable); for lead poisoning in the States providing compensation for this form of poisoning when attributable to lead and its compounds.
used in industries in which the workers are brought in contact with these substances; it is provided for under the French law (among glass polishers using putty powder); conjunctivitis due to the action of high temperatures, irritant gases and dusts is compensated in Japan.

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See also the Bibliography of Industrial Hygiene, published periodically by the International Labour Office.

Dr. D. Gilbert
(Paris).

Glove Manufacture


TECHNICAL FACTS

Gloves may be made of cloth, knitted material, wool, thread, or cotton; in these cases they are generally made by weaving and the process is included under the heading of hosiery. But the glove industry proper makes use of skins which are dressed for high quality gloves, or chamois-dressed for stout gloves, and reach the factory already prepared and dyed (see article "Hides and Skins").

As soon as the skins arrive at the factory they are sampled and then sorted, in order to detect flaws; then they are classified according to their quality, fineness, and colour.

The skins, moistened and softened, are then sent to the glove maker, who places the skin to be used in a damp sheet and rolls it up, after which he examines it to see what parts can be used for the making of gloves. The skin is then subjected to the process of spreading out (dévordage) or stretching over the edge, which consists in spreading the skin in every direction over the edge of the table and unrolling the edge by stretching the skin with the thumb over the blade of a blunt knife. The skin is then thinned or sliicked by means of a special knife. This work consists in increasing the fineness and suppleness of the skin by removing part of its thickness, whilst it is sprinkled with flour. Thinning is usually done on the flesh side of the skin, the hair side only being subjected to this operation in cases where the flesh side is to be turned outside. During this operation dust, composed chiefly of flour, is given off; but it does not present any importance.

The knife used for sliicking has a rectangular blade, sharpened only on the anterior edge; the handle is fixed at the central part of the posterior border and is held in the palm of the hand. The thumb and the last three fingers are flexed, while the index finger acts as a guide and is thus applied to the upper surface of the tool at the point where the wrist is continued by the iron. The half of the blade which forms the posterior border is to the right of the handle and rests in the second interdigital space. But some workmen place the thumb, instead of the index finger, on the upper surface of the tool. In that case the index finger is flexed and pressed against the back of the tool. Others again, especially when the blade is used, hold the handle of the knife almost at its extremity, in which case the posterior border does not come in contact with the interdigital space and the handle rests against the central part of the palm. These various ways for holding the knife depend on the degrees of force used; they explain the situations of callosities on the hands of the workers.
The workman stands in front of the work-bench with the stretched-out skin fixed by one of its extremities with his left hand, whilst the right hand works, with the fingers hyper-extended, on the skin and measured against the length of the edge of the table and against the length of the glove on the model. When that has been done they are gathered together in pairs lengthwise, the two edges being moistened with a sponge — this used to be the practice; unfortunately, workmen had a bad habit of moistening the two edges with saliva. The edges are trimmed with scissors, and then the pieces are placed in piles. If the work has caused some defect, the glove is sprinkled with a powder coloured according to the colour of the skin. As a general rule the whole glove is so treated.

**Finishing the Gloves**

The work of finishing includes sewing, embroidering, putting on the buttons or fasteners, and testing the stitching by means of glove-stretchers. The gloves are then passed to the dresser who gives them their final shaping.

Formerly (and even now in some districts), glove-finishing was done at home, and generally by the wives of the glove makers who had sewing machines. But in a large business finishing is assigned to a special department, where the sewing and embroidery work are done by motor driven machines (for details, see article "Clothing").

Coloured gloves, especially black ones, are sent once more to be dyed, so as to make up for any loss of colour and damage which may have occurred during manufacture. The work of inspection has to be very carefully and minutely done for white and kid gloves.

**Statistics**

There are no recent data available on the frequency of diseases among glove makers. According to an enquiry made at Milan in 1906 by Carozzi, the diseases which most affect glove makers were found to be typhoid fever among the infectious diseases, respiratory diseases, and, with less frequency, digestive disorders.

According to medical certificates and records of the Mutual Aid Society of Milan for the period 1895-1906 the various diseases were classified as follows: respiratory system, 50 cases, 7 of which were probably tuberculous; circulatory system, 7 cases; haematopoietic organs, 5; digestive system, 32; helminthiasis, 1; urogenital system, 4; organs of special sense, 4; infectious diseases, 16; locomotor system, 21.
Fig. 139.

Diseases of nutrition, 3; nervous system, 7; surgical and traumatic cases, 38.

Figures which are almost the same have been supplied by the Grenoble Hospital (France) for the period 1891-1899. The diseases reported are classified as follows:

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<thead>
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<th>Diseases</th>
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<td>Heart and blood vessels</td>
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<td>Central and peripheral nervous system</td>
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<td></td>
</tr>
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<td>Pulmonary tuberculosis</td>
<td>43</td>
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<td>Digestive organs and the liver</td>
<td>21</td>
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<tr>
<td>Urogenital system</td>
<td>13</td>
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<tr>
<td>Infectious diseases</td>
<td>10</td>
<td></td>
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<tr>
<td>Injuries, etc</td>
<td>16</td>
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<tr>
<td>Cachexia, dyscrasia, etc.</td>
<td>37</td>
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<td>Surgical tuberculosis</td>
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The most common forms of disease which caused incapacity for work among the insured persons of the Sickness Office of Vienna for the period 1900-1902, and among those of the Stuttgart Office for the period 1905-1906, were the following:

The data supplied by the Sickness Office of Leipzig are, on the contrary, quite favourable; but the number of days of sickness from tuberculosis is three times higher than the average for the total of insured persons. It should, however, be mentioned that the group of glove makers is not very numerous.

All these figures show that sickness among glove makers is not very prevalent (except for tuberculosis) and that, compared with the average general sickness for all age groups, it is always below this average. That is all the more true as regards the younger workers; but the percentage of cases of sickness shows a special importance in the case of recurrent cases which have almost all a fatal issue.

The longevity of glove workers is considerably curtailed, which explains the absence of data relating to more advanced ages in the statistics of sickness relating to this occupation. Appearances are deceptive and lead to the assumption of a robustness which does not exist, but, on the contrary, correspond to the blank these prematurely deceased individuals have left.

Data relating to mortality are also not at all numerous. According to the rates of the German Sickness Offices, expressed in percentages, for glove makers the heaviest mortality is found between twenty-six and forty years, at least in the case of men, which is the same period mentioned for sickness.

The figures given by the Mutual Aid Society of Vienna are somewhat similar to the foregoing.

As regards the causes of death, the Glove Makers' Sickness Insurance Office of Vienna gives the following figures (per thousand): infectious diseases, 9; tuberculosis, 8.41; nervous diseases, 0.82; tumours, 1.15; respiratory diseases, 0.98; circulatory...
troubles, 1.81; digestive disorders, 0.66; urinary troubles, 0.50.

At Prague tuberculosis represented 8 per thousand as a cause of death, and 30 per cent, of the causes of sickness among the members of the Insurance Office for glove makers.

In mortality statistics for other countries, figures for glove makers are combined with those of other leather workers such as makers of portmanteaux and of leather articles, so that it is not possible to fix real death rates for glove makers.

**PATHOLOGY**

The data which are available as to the pathology of glove makers are neither numerous nor recent. So it is necessary to fall back on the hygiene and sanitary conditions of this industrial class, and on articles and enquiries which have appeared some ten or twenty years ago.

There can be little doubt that the conditions under which the glove maker used formerly to work, as regards the state of the workplaces, piece work and work at home after work in the workshops, were responsible for weakening the general resistance of the body. It was owing to those conditions that they were exposed chiefly to pulmonary affections and to tuberculosis in particular (according to Carozzi and Bauer), to rheumatic affections, and to heart disease. But, in addition to these diseases which are not characteristic of the occupation, certain special pathological conditions are met with among glove makers which should be regarded as specific. Thus, the hand shows changes which are found with a fair regularity in all the workers: coloration of the epidermis with the various colours in consequence of work on dyed skins; and a deposit in the folds of the skin and under the nails of dust which is generated during work and made up of a mixture of leather-waste, flour and colouring matter. The left hand is often less developed among right-handed persons; the palm has a thickened epidermis all over, especially near the wrist and on a level with the pisiform where a small serous bursa has even been described by Montaz. The last four fingers may be placed into forced hyper-extension on account of relaxation of the metacarpophalangeal articulation.

The use of the knife with the right hand leads to the formation of callosities, the position of which is not constant, on account of the various ways of holding the knife. These callosities, which are situated in the palm on a level with the head of the first and second metacarpals (Jullien), are often painful, and dissection has revealed an inflamed and suppurating serous bursa. In other cases callosities are found at the heads of the third and fifth metacarpals, and sometimes of the fourth; in the space which separates the thenar and hypothenar eminences; and less frequently on the median side of the hypothenar eminence and of the fold at the bend of the first two phalanges. The heads of the second and third metacarpals between which lies
the back of the knife show a separation in consequence of relaxation of the transverse ligament (Montaz); the index finger, during work, exercises a con- tinual pressure on the back of the knife often shows a flattening, like a spatula, of the small phalanx. Among elderly workmen the phalangeal bones become deformed by flattening and the finger undergoes a slight movement of rotation on its axis, its anterior face tending to become internal. The last three fingers are often in a state of semi-flexion in consequence of traumatic contraction of the palmar aponeurosis.

The phalanx of the thumb becomes flattened into the shape of a spatula and bent back on the back of the hand. A wide separation is found in the second interdigital space, due to the pressure exercised by the knife which rests there. The dorsal surface of the thumb and of the last three fingers, at the level of the second joint, almost always show small callosities caused by the rings of the scissors. Other callosities may be situated along the ulnar border of the right hand in consequence of the blows struck on the pattern.

Further, a very painful small callosity may often be noted at the corner of the nail, especially of the index finger, of a semi-circular shape which is clearly of traumatic origin (Carozzi).

The attitude adopted by the workman leads to a deformity which is shown by the higher position of his right shoulder in comparison with the left.

But deformities of the vertebral column and the lower limbs cannot be proved.

When the men work with naked feet, callosities and ulcerations may be observed on them (Holtzmann). Cases of furunculosis, as well as ulcerations in the interdigital spaces, may also be seen, resulting from the use of mordants with an alum base (Holtzmann).

Cases of poisoning have also been reported from the use of white lead on white gloves and of benzene for cleaning gloves soiled during work.

Among women the various processes have an unfavourable effect on the body.

The sewing woman generally adopts a position at her machine which is far from hygienic. This position and the various movements which are associated with it lead to deformity of the vertebral column. This condition is all the more pronounced when the woman has commenced work as a girl, in which case her bodily resistance may have been lessened by anaemia and associated poor nutrition.

With regard to trouble from sewing machines, see article "Clothing Trades".

Fatigue of the leg caused by working at pedal machines may cause sciatica (Seeligmüller), or a chronic myositis (Strümpell), or more frequently cramp in the lower limbs.

With regard to the organs of sense, myopia has been observed.

HYGIENE

The measures of hygiene to be observed in workshops where gloves are made are the same as for any other industry — spacious rooms, which are well ventilated and well lighted. Thorough cleanliness should be insisted on, for the work involves the use of organic raw materials which give off dust and disagreeable odours.

It is also advisable to adopt every means for ameliorating the hygienic conditions for the persons employed; by using small sponges to moisten the edges of the cut pieces; by protecting their hands when tools are used which may in the long run cause lesions or thickenings; and by providing spittoons.

As regards women's work, it is desirable to employ more and more motor sewing machines with suitable seats. Defects of eyesight among workmen should be detected by periodical examination by a specialist; and the defective should be called upon to wear correcting glasses.

Whilst in some cases the industry is centralised in large works, which assures to glove makers good conditions of work, it is not the same when glove making is carried on as an industry in the homes of the workers. In this case any control is very difficult and in consequence the work is characterised by all the well-known troubles associated with home work (see that article). Steps should also be taken to prevent, as is done by some Governments, workmen taking home extra work, as is the custom in some districts.

There are no legislative provisions for this industry.

BIBLIOGRAPHY


Glues are substances with strong adhesive properties. The principal glues are gelatine glues and are derived from animal tissues and clippings. In the manufacture of these glues there are used: (a) skin debris ("skin or hide glue") obtained from abattoirs, tanneries (goat, rabbit, hare skins), old gloves and leather waste freed from tannin by appropriate treatment; the skin of certain kinds of fish is also used (codfish), which gives a glue which must not be confused with the glue called "fish glue"; mention should be made, too, of the glues made from horn and hooves; (b) bones ("bone glue") represented by the residues from treated bones, degreased, granulated bone or crude bones (from the butcher or from household refuse); (c) fish residues ("fish glue"); the skin and cartilaginous portions, clippings and debris from the manufacture of tinned fish, principally cod.

Under the name of "fish glue", however, glues are sold made from the intestines of goats, pigs, and other animals.

**Industrial Processes**

The processes differ according to the raw materials used:

**Skin or Hide Glue**

After sorting and cleaning, the raw materials are treated for fifteen to forty days with slaked milk of lime ("liming"), then delined, either by acids (juice of sour tan) or by the carbonic acid in the air (carbonatation). In this condition the solution can be dried in the air, yielding products sold under the name of diverse commercial names; but usually the conversion into gelatine is conducted in autoclaves under the action of steam and then of hot water (boiling). The solution obtained is concentrated, decolorised (by means of sulphur dioxide, sodium hyposulphite, or peroxide of hydrogen, then clarified (either by decantation or by filtration) and run into troughs. After cooling in the open air or in cold water, stripping the mould yields blocks of gelatine which are cut and then dried over screens in well-ventilated and heated (27°-30° C.) chambers — sometimes in hot air drying tunnels. The dry blocks are sometimes ground into fine dust.

The sheen which gives a brilliant appearance to dried gelatine is obtained by plunging the gelatine into hot water (which dissolves the surface slightly) and brushing it gently.

**Bone Glue**

After cleaning (washing in hot water) in revolving drums made of perforated sheet iron and rinsing in cold water, the bones are broken up (in cylindrical fluted rollers or in grinding machines), freed from fat and subjected to extraction by hot water (to obtain the alimentary gelatine from the bones fresh from the butchers), or in an autoclave (heating the bones with water approaching atmospheric pressure; then the pressure is increased to reach boiling point; the residue serves very well for the manufacture of superphosphates and animal charcoal), or by hydrochloric acid which converts the tricalcium phosphate of the bones into soluble monocalcium phosphate. The solution, reprecipitated by lime into the state of bicalcium phosphate is utilised as a manure or for the manufacture of phosphorus. The insoluble ossein is sold as such in commerce or boiled directly for making glue.

**Fish Glue, Isinglass**

The purified offal degreased and treated by an acid to separate the mineral portions is converted into gelatine according to the methods used for skin glue. When finished isinglass is in the form of rings, leaves, thread, etc. After the country of origin, it is called Russian isinglass, North American, East Indian, Chinese, Brazilian, Cayenne, etc.

Different substances are made, along with ordinary glues, such as liquid...
**strong glue**: a thick solution of strong glue to which an acid is added (nitric or hydrochloric), in order to hinder gelatinisation; **white glues** (Russian opaque glues) obtained by addition of white chemicals (sulphate or carbonate of lead, zinc white); gelatine obtained by concentrating good glue to a pasty consistency, adding a tenth of powdered sugar and citric acid; gum obtained from the residue of gloves as the starting point; **mastic glue**, for repairing glass and china and made of a mixture of glue and adhesive substances (turpentine, starch, etc.); **glycerine glue** and **diamond glue** obtained by gelatinisation of fish glue with dilute alcohol in which mastic is dissolved, etc.

Here it may be well to mention the substitutes for gelatine glues, which take the form of watery solutions of various substances:

- **Paste** obtained by an emulsion of starch or flour in water heated slowly to 60-70° C. until the mass has sufficiently set; it is used principally for sticking papers and bills; **dextrin paste**, used principally for dressing and finishing; **casein glue**, obtained by making a paste of casein with a little water and adding a hot concentrated solution of caustic soda or bicarbonate of soda, borax, tungstate of soda, ammonia, in such a way as to make a thick mucilaginous paste which is mixed at the desired consistency with a little water at the appropriate moment.

- **Vegetable glues** or albuminoids ("glutinous glues"), such as glues with a gum base (watery solutions of soluble gums derived from certain acacias), employed mostly as thickening agents in printing cloth, etc., and glues with mucilage as a base (derived from different seaweeds).

**Uses**

Gelatine is used as a clarifying agent in the manufacture of alimentary products (syrups of wines, beer), in the preparation of certain pharmaceutical substances (disks, capsules, cachets, etc.), as a coating in photography (preparation of films) in heliography, chromolithography, letterpress printing, and for making edible gelatine.

Glues are used in numerous industries, notably those of wood (cabinet making, joinery, marquetry), of paper (making of papers, cartons, gummed papers, labels, emery paper cloth) bookbinding, polygraphic arts (manufacture of inking rollers, copying pastes, multigraphing), hatmaking. It is still used in painting buildings, in the preparation of colours, washes (opaque glues) to cover wooden objects; in the preparation of adhesive court plaster or sparadrap (very thin silk tissue coated with a solution of fish glue, honey, balsam of Peru, tincture of benzoin and dilute alcohol); impermeable tissue (layer of glue spread on tissue and then immersed in a bath of tannin); in the manufacture of small flexible figures, and even of articles sufficiently hard to be polished and brightened in imitation of horn and ivory; etc.

**Sources of Danger**

The sources of danger in the manufacture or use of gelatine glues are, apart from the odours given off in the warehouse, the raw materials, or in certain processes ("liming") the risk of infectious diseases, organic dusts, and the action of certain products given off or used in the industrial processes.

The risk of infectious disease due to debris coming from animals which have died of transmissible diseases are especially important during the sorting and cleaning of the raw materials, because the later operations to which they are subjected are equivalent to disinfection.

Dust is given off almost exclusively in the operations of grinding the dry glue into fine powder.

Among the injurious substances given off in the course of the operations, mention should be made of nitrogenous fermentation, ammonia, mercaptan *(especially in the warehouse)*, volatile fatty acids, sulphured and arsenured hydrogen gas, acrolein, etc. Taking up with acids the residues of boilers for the extraction of fats exposes the workmen to acid vapours. In some cases escape of nitrous fumes has been described.

Among the substances used in the course of the different operations mention should be made of hydrochloric, nitric, and sulphuric acid, sulphurous anhydride in decolorising, formic aldehyde added to the glue to hinder putrefaction; the dichromates used to render the gelatine and glues insoluble; certain solvents (benzene, benzol, acetone, carbon bisulphide, chloride of sulphur, turpentine, carbon tetrachloride, etc.), as well as different substances used for the preparation of different glues.

**Statistics**

These are very few. In 1918 in an **American** glue factory 3 cases of poisoning by sulphuretted hydrogen gas, of which 2
were fatal in a few minutes, were reported among workpeople who had cleaned animal hooves.

The German inspectors of factories described 2 cases of dermatitis (purulent eruptions) which occurred in 1920 among workmen in a furniture factory near Frankfurt and were due to a glue containing lime.

In Switzerland 3 cases of ulceration due to glue were reported in 1922, 2 in 1924, and 3 in 1925.

**PATHOLOGY**

Septic pricks may be followed by either inflammatory lesions, more or less troublesome, or specific diseases such as anthrax.

Dust from glue, in addition to the irritative lesions affecting the skin, may damage the mucous membrane of the eye (blepharitis, conjunctivitis), and especially the respiratory mucous membrane (bronchitis).

The products given off or used may produce lesions of various kinds: formic aldehyde can oxidise into formic acid and set up irritative dermatitis.

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In most countries glue factories come under the designation of “offensive trades” and are subjected to restrictions of a hygienic nature, mainly directed against the odours and emanations emitted. Among these measures the following should be mentioned: they must be situated away from dwelling houses; apertures in buildings facing a public road or right of way must be kept closed: floors of workrooms and courts are required to be constructed of impermeable materials and stores of non-inflammable material; necessity of having powerful ventilation; frequent washing of workplaces with pure water or with water to which chloride of lime is added and similar treatment of carls and other means for transporting the raw materials. Requirement to place the bones used in barrels and to sprinkle charcoal over them; to treat the raw materials before they have commenced to putrefy; limitation on the amount to be used daily; prohibition of manufacturing artificial manure; obligation to provide covers for coppers in which cooking is done and to provide over them hoods communicating with the outside air by vent pipes in which a strong draught is maintained or to connect them up with the factory chimney in order to carry off the steam and fumes; obligation to raise the factory chimney stack 3 to 4 metres above the level of surrounding chimneys over a radius of 50 metres. As the residues from the manufacture carried on putrefy quickly, they ought to be removed every day to fields and be buried deeply there or sent to artificial manure factories. Water from soaking and liming vats ought to be used as manure or treated by calcium chloride. Washing water and effluents containing organic matter putrefying readily ought to be decanted and disinfected.

To prevent emanations coming off, operations should be conducted in closed vessels and the gases and vapours be burnt in the furnaces or in special apparatus.

To guard against the risk of infectious diseases, besides ordinary prophylactic measures, disinfection is certainly the best means and might be done by the following processes: in the United States, for example, boiling water is used for fifteen minutes or water at a temperature of 82° C. for four hours, or with a 2 per cent. solution of hydrochloric acid for twenty hours, or a 1 per cent. solution for forty hours; by the action of milk of lime; by sun-drying.

Against dusts and matters given off or used, such customary measures as are ordinarily employed should be taken according to the nature of the products.

Transport of raw materials should be effected in closed receptacles, to be cleaned or disinfected after use. Overalls, means for cleanliness, and first-aid provision are among the principal effective preventive measures.

**LEGISLATION**

Boys of less than sixteen years of age are prohibited from employment in glue factories in Canada (Quebec) and in Greece: of less than fifteen in the manipulation and sorting of bones, horns, etc., in glue factories in Italy: female young persons under eighteen in Greece and under twenty-one in Italy. Compulsory disinfection of raw materials in certain circumstances is required in the United States and in Canada: compulsory disinfection of receptacles for the transport of raw materials in Canada.

Compensation for septic poisoning from the manipulation of animal by-products is required in Queensland and Victoria.

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Goggles
(Protection of the Eyes in Industry)


Protection of the eyes constitutes an essential point in industrial hygiene. Few organs are really more exposed to injuries and damage of every kind; few accidents are at the same time so painful and few industrial processes are exempt from all risk in this respect.

The study of the hygiene of the eye is too specialised a subject and would involve going much too deeply into detail, and therefore this article is limited to the protection to be afforded against accidental damage from external agents.

Some processes, such as welding by the electric arc, demand protection not only of the eyes but of the whole face and head — a protection now given by one and the same apparatus. Study of the question of how to protect the eyes, therefore, is closely related to the general question of protection of the head by goggles, masks, helmets and hand screens.

Goggles may be classed in three main types: (1) glasses container in rigid metal frames without side screening, (2) the same with side screening, and (3) glasses let into flexible frames which can be moulded exactly to fit the face.

Processes Requiring Protection with Goggles

No hope can be held out of finding a universal means of protecting the head and eyes suitable to all industries; industrial processes are too numerous and variable, and the risks too different, and conditions under which goggles may have to be worn too diverse.

Several types of goggles are necessary from which to choose the kind adapted to the particular process. The following classification may be useful:

(a) Work in which the eyes have to be protected against the projection of particles of appreciable size: engraving, caulking, riveting, etc.

(b) Work where it is necessary to keep out of the eyes light particles: grinding; polishing, scouring, etc.

(c) Processes necessitating protection of the eyes against the penetration of very fine particles: cleaning of cast iron with the sand blast, etc.

(d) Processes in which there is risk of splashes from very hot matter: pouring, casting, tapping, tinning, japanning, galvanising, etc.

(e) Processes where protection from gases, fumes or acids is called for: chemical industries, manipulation of tar, etc.

(f) Work necessitating the interception of injurious luminous rays; burning by means of the blow-pipe flame, steel manufacture, etc.

(g) Work requiring special interception of light rays; electric arc welding.

(h) Work in which protection against dust and wind is necessary; motor driving.

(i) Work exposing to strong reflection.

General Characteristics of Goggles

All goggles should:

(a) offer complete protection against the risk, from whatever direction it is likely to come;

(b) sit well on the face without causing discomfort;

(c) give an unimpeded view;

(d) allow the requisite amount of light to pass through for the work to be effected;

(e) allow the glasses to be changed without difficulty and without any special instrument;

(f) resist corrosion;

(g) stand fairly rough handling;

(h) be capable of complete disinfection;

(i) neither irritate nor wound the skin they come into contact with;

(j) allow glasses necessary for correction of errors of vision to be worn at the same time;

(k) be composed of interchangeable pieces;

(l) all parts must be indestructible by heat;

(m) carry an identification mark.

The glass in the goggles must be hard, free from striae, air bubbles, streaks or other defects. Both sides should be perfectly smooth and parallel, unless intended at the same time to serve to correct defective sight. Unless particularly specified they should be colourless and quite transparent, i.e. allow 80 per cent. of the light given out by a standard lamp to be transmitted (see the optical test b).
The goggles should carry an identification mark. The frame should be adapted to the shape of the face, be kept in a position sufficiently distant from the eyes not to inconvenience the movements of the eyelids and keep in place fragments of glass which crack. The glasses ought to be fixed in their frames as simply as possible so as to rest constantly in their place and be easily changed.

The attachments of the frames should be hinged in such a way as to allow of the goggles being folded and carried easily in a stiff case.

**Special Characteristics of Different Types of Goggles**

Class A. — Protection of the eyes against the projection of particles of appreciable size (graving, caulking, riveting).

The use of types 1, 2 and 3, and masks and helmets may be permitted. The goggles should be light permitting ventilation for the eyes. The thickness of the glass should be at least 2.5 mm. A certain number ought to be tested against breakage by subjecting to a blow (see page 901, d) with a height of fall of 54 cm. The glasses which have served for the test ought not to be used. None of the openings in the side screens should be more than 1 mm.

The types shown in figs. 143 and 144 are, however, the most suitable, while that of fig. 145 is to be particularly recommended for riveting, coppersmith’s work, and stone-breaking and chipping.

Class B. — Protection of the eyes against penetration of light particles (grinding, planing, scouring).

Types 1, 2, or 3 may be permitted. The glasses should have a thickness of at least 1 mm. Testing is not indispensable — but not amiss — and from a height of fall of 25 cm. The types represented in figs. 146 and 147 are, however, very suitable.

Class C. — Protection of the head and face against penetration of extremely fine particles (cleaning pieces of cast iron, sand blasting, etc.).

The helmet is the only protection suitable. It should completely envelop the head and neck and rest on the shoulders so as to exclude every particle.

The air breathed is brought in under pressure through a flexible pipe entering at the top of the helmet.

Propulsion may be effected by a blower-fan of the kind used at a blacksmith’s forge or by an ordinary fan of low pressure. After having passed into an expansion valve to maintain a constant pressure of 0.2 of an atmosphere over and above atmospheric pressure, the air is filtered through layers of fine cloth arranged in a metal casing (fig. 148). These layers are cleaned and renewed as often as the use to which they are put requires. Under no circumstances may the air used be supplied by an ordinary compressor, because such air carries with it harmful products from the combustion of the oil used in lubricating.

In order to lighten the movements of the workman, the pipe which brings the air can be hung at a little distance from his head by a chain and counter-weight.

Fig. 149 illustrates two satisfactory types.

Class D. — Protection of the eyes against splashes of very hot liquids (casting and manipulation of molten metals, tinning, etc.).

Protection can be given by a helmet made of vulcanised fibre or of wire gauze with a mesh of at most 0.75 mm. provided with one or two windows and covering the whole head, the base of the neck being protected behind and before by a leather flap (fig. 150).

The glass of the windows should be at least 2 mm. in thickness; testing is not indispensable but useful, the height of fall being reduced to 25 cm.

Class E. — Protection of the eyes against gas, fumes or acids (chemical industries, manipulation of tar, etc.).

Suitable protection is afforded by goggles of type 3, masks and helmets; that shown in fig. 151 is very suitable. The edging round the eye-pieces should be of rubber as well as the attachment cord.

The ventilation of the goggles should be such as not to allow of the passage of any splash of acid.

If the fumes of acid vapours are very injurious to the eyes the orifices must be closed, and the margin of the eye holes provided with pneumatic rims, assuring perfect adhesion to the skin.

The masks should be of metal, vulcanised rubber, or fibre, and have no opening in front other than the eye holes; they should protect the whole face.

The helmets should comply with the same conditions as for Class C.

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1 See p. 896 for the three types of goggles.
If the work is likely to injure the surface of the glass other materials can be used, such as acetate of cellulose, provided it is free from all striae, bubbles of air folds and other defects.

Class F.—Protection of the eyes against injurious light rays emitted in burning by means of the blowpipe, Martin furnaces, converters, etc.

Goggles of types 1, 2, 3, and masks and screens may be permitted. The bridge and all parts of the goggles coming into contact with the skin require to be covered with some heat-resisting material. The eye-pieces require to be large and deep to protect against the heat. The frames must be made of opaque material and the ventilation openings arranged in such a manner as to prevent the passage of any ray.

The masks and screens should be made of vulcanised fibre, asbestos cloth or similar material, light, opaque, incombustible and heat resisting.

When not in use an arrangement such as that illustrated in fig. 152 should allow of the mask being tilted on to the forehead.

The total weight of the apparatus ought not to exceed 200 grammes.

When tested (see the optical test) the glasses ought not to let more than 1 per cent. of the radiant energy of any wave length less than 400 millimicrons,
GOGGLES

nor more than 50 per cent. of the total radiant energy pass through.

These conditions are most readily complied with by deep green, greenish-brown, greenish-yellow, or greenish-amber coloured glasses

For furnace work smoked glasses will suffice, the shade varying with the luminous intensity to be borne.

For working aluminium deep blue will serve.

Coloured glasses are best protected by plain glasses outside them, complying with the conditions already specified, and changed as soon as they become affected by the action of the metal splashes.

The total thickness of the glasses should not exceed 3 mm.

As the visual acuity of workmen varies, the glasses chosen for a workroom ought to be ordered on a scale such that each man can choose the glasses that suit him 1.

Class G. — Protection of the head against injurious light rays emitted by burning or cutting with the electric arc.

The only suitable protection is a mask or screen.

Not only must the eyes be protected, but the whole of the exposed part of the skin.

The masks and screens require to be of opaque, incombustible, heat-insulating material.

They are provided with side pieces so as to cover the whole of the face, ears and neck.

The mask mounted on a band allowing it to be moved above the head by simple rotation is recommended (fig. 153; the illustration on the left shows a workman who has removed the mask momentarily).

The total weight should not exceed 600 grammes.

The window should be rectangular. On being tested (see later) it should not allow more than one per cent. of radiant energy of any wave length less than 400 millimicrons, nor more than 10 per cent. of the total radiant energy, nor more than one per cent. of the visible light to pass through.

One or other of the following conditions prove satisfactory:

(a) Two glasses, one red and the other green, with a white glass in between; preferably all three should be lead glass, especially the white, because lead glass absorbs the ultra-violet rays.

(b) Four glasses — two of ruby and two of cobalt.

Brown or greenish-brown glasses can also be used if they comply with the conditions mentioned above 1.

The coloured glasses should be protected by plain glass (see above) and the thickness should be at least 3 mm.

Any air bubbles in the glass renders protection against chemical rays ineffective.

The personnel working or passing near places where electric welding is being carried on should be protected by fixed or movable screens 2 metres high made, e.g., of frames of jute dyed with a colour intercepting the ultra-violet rays (a mixture of oxide of zinc and lamp black). The walls near by should be distempered with this colour.

Class H. — Protection of the eyes against dust and wind (chaufeurs).

Types 1, 2 or 3, may be used. Those illustrated in fig. 146 answer well.

Testing the glasses is not indispensable, but can usefully be carried out, reducing the height of the fall to 25 cm.

Class I. — Protection of the eyes against reflection.

Types 1, 2 or 3 suffice for this. Type 1 is enough. Exposed to the standard source of light (see later), the glasses should not allow more than one per cent. of radiant energy of any wave length less than 400 millimicrons to pass through, nor more than 50 per cent. of the visible light.

Tests to be Applied on Receipt

The number of samples to be tested turns on the nature of the work for which the goggles are required and the stringency with which the specified conditions have to be observed.

1 See preceding footnote.
The test apparatus, shown in fig. 154, comprises a mobile electro-magnet, capable of being adjusted on two vertical rods at different heights, and supporting a steel ball 16 grammes in weight and 16 mm. in diameter.

The glass to be tested is placed in its frame upon a pad of india-rubber 6.5 mm. in thickness, resting on a hard footing of wood which forms the base of the apparatus in such a way that the ball in falling may strike the centre of the exterior surface of the glass.

The ball is allowed to fall from the desired height ten times. If one glass in six breaks the test should be tried with four; if one of the lot is broken the whole lot should be rejected.
OPTICAL TEST

(a) In the case of glasses specially intended for welders a rapid method of selection is by means of a lamp of 400 international candles. The glasses are interpolated between this source of light and the eye and, if satisfactory, they should appear brown or greenish brown. If reddish in colour they should be rejected. Defects in manufacture or in texture such as bubbles, striae, etc., are detected in this examination.

(b) For a rigorous or exact optical test, use is made of a standard electric incandescent lamp with a filament of tungsten in a gaseous atmosphere, of 200 watts at 110 volts, i.e. 0.8 watt per candle.

Special apparatus is necessary and the work must be carried out by an experienced person.

The intensity of visible light is judged by the photometer. Invisible radiant energy is measured by its calorific action on a thermo-electric couple.

HEAT TEST

After having been heated to a temperature of 20° C. the glasses in their frames are dipped into boiling water.

They must not crack under the test or be affected in any way.

THE FRAME — CORROSION TEST

The metal parts of the frame when soaked for fifteen minutes in a boiling solution of 10 per cent. (in weight) solution of sodium chloride, and then into a similar solution at the temperature of the surrounding atmosphere and then left exposed to the atmosphere for twenty-four hours, should show no trace of corrosion.

MECHANICAL TESTS

(a) Test for flatness. — The right glass is placed and kept flat securely with the external face downwards upon a solid and perfectly smooth support, in such a way that the left eyeglass and half the bridge hang free of the edge of the support.
at a slightly inclined angle. A spring balance is fixed to the free end of the frame and tested with a weight of 225 grammes. After removing the weight no change or permanent damage should be observed in the frame.

b. Transverse test in section.— The operator holds in his hand vertically the right eyepiece of the frame to be tested, and places the left eyepiece on one of the scales of a balance of which the other scale carries a weight of 1,821 grammes. Pressure is gradually exerted until equilibrium in weight is established; the frame is then examined and should be free of any defect.

c. Test for the frames.— The test for breakage already described should be carried out on glasses mounted in their frames. These should stand the test without undergoing any damage.

d. Test of the hinges.— If the frame is not of one piece and the eyepieces are fixed rigidly on a bridge to go over the nose the hinges should be subjected to a test of resistance and durability.

For this the goggles which have been subjected to the tests (a), (b), and (c) can be used.

The operator takes an eyepiece with the glass inside in each hand, the thumbs being placed on the external surface near the bridge and the fingers on the internal near the point of junction of the bridge with the eyepieces. The frame is then gently bent perpendicularly to the surface of the glasses until the outer surfaces are brought into view; the two extremities of the frame being in contact.

The goggles are then brought back to their original form. In this test there must be no cracking, nor any distortion of the joints.

Cases

Each pair of goggles should preferably be provided with a case having its corners rounded and capable of standing sterilisation in boiling water.

Maintenance of the Goggles

Sterilisation.— Goggles should not be given to a second person except after sterilisation.

For this purpose they may be kept in boiling water for five minutes, or placed in a solution of formalin - 32 grammes of formaldehyde to a litre of water.

The parts of the goggles or masks which might be damaged by these methods must be sterilised separately with some antiseptic gas; formaldehyde is recommended.

Maintenance, repair and storage of the apparatus.— A responsible person should have assigned to him as his duty to distribute and adapt the goggles or other means of protection for each worker who has to use them. He should periodically inspect them. They must be made to sit as comfortably as possible.

Goggles and spares in sufficient number must always be kept in reserve.

Broken or cracked glasses affecting sight or dangerous to the eyes must be immediately replaced.

Before being given out a second time the goggles or means for protection must be completely repaired.

Cleaning.— A brush for cleaning should be kept in each cupboard or tied to each helmet or mask and renewed when worn out.

Legislation

Generally speaking the provision of goggles or adequate means of protection against work in the presence of gases, fumes, splashes from corrosive liquids, dusts, intense heat or light rays, is statutorily required by all governments. For details, see the Legislative Series of the International Labour Office.)

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L. Deladrière. (Engineer, Brussels.)
Gold

French: Or. — German: Gold. — Italian: Oro.

Gold is generally found in its native state (nuggets) in quartzite rocks, in gold-bearing pyrites, in alluvial deposits and sand brought down by certain rivers. The countries rich in gold are South Africa (Witwatersrand, Transvaal, Rhodesia), North America (California, Alaska, Colorado, Nevada, etc.), Mexico, Australia (Coolgardie, Kalgoorlie), etc.

Pure gold (symbol Au) is a brilliant, very malleable metal (it is possible to obtain leaves the thickness of 0.00009 mm.), of a yellow colour, very ductile and a good conductor of electricity and of heat. Its specific weight is 19.30-19.50, and its hardness 2.5. It is insoluble in almost all solvents and is only attacked by aqua regia, chlorine and potassium cyanide in the presence of oxygen; it forms an amalgam with mercury.

Technical Data

For gold mines, see that article.

The most usual method of extraction of gold consists in levigation of sand and gold-bearing rock. The water removes the sand, leaving the grains of gold in the bottom of the gutters. In order to avoid loss, recourse is had to the amalgamation process. The gold-bearing ore is, after being well pulverised, brought into contact with mercury, which extracts a large part of the gold. The precious metal is recuperated by making the mass of ore pass over plates of amalgamated copper or silvered copper. This process is not applicable to gold-bearing minerals containing pyrites or arsenic, which are treated by electric amalgamation (Rae). Minerals of complex composition are submitted to a process of fusion with lead, which dissolves the gold. The gold-bearing lead obtained then undergoes cupellation.

Another process, regarded as the most advantageous, is the chlorine process (Platiner), applied to the ores which have previously been submitted to roasting in order to eliminate sulphur and arsenic. The gold chlorate thus obtained is treated by ferrous sulphate. The gold, precipitated in the form of a fine powder, is purified by washing, dried and melted with borax.

At the present time, recourse is principally had to the cyanide process (Forrest, 1846, modified by Siemens), based on the property possessed by gold or even gold sulphate of forming a soluble combination with potassium or sodium cyanide. The gold is precipitated in the solution either by sheets of zinc or aluminium (Forrest) or by electrolysis of the cyanide solution (Siemens). The gold, which is deposited on the cathodes, must then be submitted to cupellation.

For ores which do not easily yield up their gold, the electro-chemical process is followed (Clancy) by a process which demands previous roasting. The pulverised ore is placed in an electrolytic bath containing sodium cyanide and cyanamidé of calcium and of potassium iodide.

The impure gold obtained by these processes is submitted to refining by heating with nitric or sulphuric acid, in which it is insoluble. There exists besides, an electrolytic process of refining (Möbius, Wohlwill).

Liquid gold, or gold lustre (Glanzgold, or brillant), is a thick, greasy, transparent liquid, the composition of which remained for a long time secret. It is prepared by dissolving sheet gold or leaf gold in aqua regia. The salt thus obtained is transformed by means of sulpho-resinates or resinate which is dissolved in a mixture of essential oils. The composition of these oils and the manner of dissolving the resinate remain the secret of each pottery maker, since it depends on several factors (type and texture, etc., of the pottery clay). It is known, however, that the following ingredients are in question: oil of camphor, or rosemary, and of fennel, etc. Volatisation of the gold during heating and its detachment are prevented by simple friction by introducing into the mixture a flux (bismuth) which fixes the gold in the glazing mixture.

Metals derived from platinum, rhodium and iridium ores are also introduced in the form of a resinate rendered soluble which gives with the gold an alloy, proof against volatisation.

Gilt is much less used since the discovery of liquid gold. It is found on the market in the form of a powder (45-90 per cent. of gold) or liquid (15-30 per cent.), which is none other than the fine suspension of the former in liquid gold. The product in question is an intimate and finely pulverised mixture of metallic gold, oxide of bismuth, metallic silver and oxide of mercury in proportions which vary considerably according to the shade of gold which it is desired to obtain.

Uses

Gold is used either in leaf form for applied gilding or as a copper or silver alloy by goldsmiths.
Hot gilding, or fire gilding, is a process the use of which goes back to a very remote period. The use of gold amalgam was already known in the time of Pliny and the dangers of mercury poisoning were described as far back as the beginning of the seventh century. The practice of hot gilding or fire gilding involves several operations: preparation of the amalgam by heating in a crucible some pieces of fine gold with a quantity of mercury, representing eight to fifteen times the amount of gold. The amalgam, after cooling by water, is then squeezed through a chamois leather for removing the excess mercury present.

In gilding properly so called, there is first of all applied by means of a small brush a solution of mercury in nitric or hydrocyanic acid, after which the amalgam is applied. The object thus covered is put into a wood charcoal furnace for a few minutes in order to render the amalgam fluid and cause it to penetrate into all the fissures. On withdrawal from the furnace, the article is dried with a brush or with a cotton cloth with the object of spreading the amalgam over it in a uniform manner.

For the gilding of jewels a fluid amalgam is used. Gilding by a hot process is applied to the tips of lightening conductors and crosses, cupolas on churches and objects of plastic art, etc. When strong gilding is required, the operation is repeated until the requisite quantity of gold amalgam is obtained. This process is, however, less and less employed.

Beaten gold is at the present time still manufactured by hand in several countries, being effected by men and women workers who use heavy hammers and slips of rutan for the purpose. Very pure gold, to which a certain amount of gold leaf or bronze powder, the latter being capable of application by either a dry or a wet method.

The salt employed for galvanoplastic gilding is a double cyanide of gold and potassium containing 68.4 per cent.

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gold. On account of the value of the metal which it contains and of the very low rate of consumption, this salt is generally made in a laboratory where all necessary precautions are taken against in case of breaking of the apparatus.

The consumption of gold in the pottery industry for decorating glass, pottery and especially china is considerable, though each object does not receive more than a few milligrams of gold. The application of a composition containing 10-12 per cent. of gold is effected by means of a brush. The glaze may be ready after drying without special annealing, though in some cases annealing at a temperature of 700-800° is required. Thereafter the metallic lustre of the gold is obtained by burnishing with agate or bloodstone, or by polishing by means of a scratch-brush of brass wire. The pottery articles are then sometimes submitted to cleaning by means of an application of vinegar and white lead.

Sources of Danger

For the extraction of gold, see article "Gold Mines". Hot gilding, apart from contact with the amalgam and mercurial liquid used, exposes the worker to the risk of inhaling noxious fumes. In fact, a worker who manufactures, on an average, 3 to 4 ducats (a ducat = 3.489 grm.) uses a quantity of mercury varying between 100 and 120 grm. The maximum amount produced has been 22 ducats, corresponding to a volatisation of 660 grm. per worker.

The risk of mercury poisoning does not only constitute a danger for the gilders, for there have also been reported cases amongst chimney sweepers who have cleaned chimneys in gilding establishments (Patissier).

The manufacture of beaten gold is very tiring, but few data are available in regard thereto. There have been reported merely rubbing away of the radial side of the right thumbnail and the presence of dust containing gold under the nails.

The more and more extensive use of gold leaf has resulted in a wide extension of the manufacture and utilisation of mosaic gold (or mustif) (see article "Tin").

As regards gilding on wood, there must be taken into account the risk from colours with any kind of lead basis. As far as the lacquer is concerned, Koelsch has been able to report three cases of lead poisoning. Lacquer also presents a health risk for the workers, by reason of other substances employed (denatured alcohol, methyl alcohol, pyridine), to which has been attributed "polisher's itch", met with fairly frequently amongst gilders on wood. In burnishing and cutting, the fumes of turpentine have been held to be the cause of respiratory oppression.

Finally, in the application of gold leaf, workers complain of the exhausting effect of blowing by the mouth. This inconvenience is now practically non-existent, the operation being effected mechanically. The application of bronze powder gives rise to the production of dusts which may have a more or less harmful action, according to their composition. Liberation of such dusts is of course absent where the wet method is followed.

In general, the German authorities are of opinion that gilding on wood only gives rise to dangers of relatively slight import and that the one lesion which of necessity deserves the attention of the medical authorities is "polisher's itch".

In spite of the absence of accurate statistics, it may be said that the morbidity and mortality rates in regard to this occupation would not appear to be — in Germany at least — very high, taking into consideration the fact that the number of aged polishers and gilders is fairly considerable.

What still leaves much to be desired is the hygienic state of the workrooms.

Pathology

The pathology of workers in gold manufacture is similar to that of jewellery workers (see that article). It suffices to record here the affections and lesions met with by certain authorities amongst workers engaged in gilding, in making beaten gold and in polishing.

During gilding on metal, the workers are chiefly exposed to the action of nitrous fumes given off during scouring, or the mercury fumes where mercury gilding is effected.

In the manufacture of gold chains there has been frequently met with, especially amongst women polishers, eczema due to the use of colza oil, the disease being sufficiently serious to oblige the women to give up their work. Some cases of syphilis have been reported amongst workers on gold, due to the use in common of the welding blowpipe (Finger). The beating of leaf gold may cause typical stigmata of the hands (Winkler). Lewin has described chemical burns on the hands amongst gilders due to the
soluble salts of gold and ammonia and especially to the lime used in polishing. Deep-seated impregnation (of a mechanical origin) of the skin and more particularly of the internal side of the left thumb has been described as affecting workers occupied in sawing small gold chains (see also article "Watch and Clock Makers").

HYGIENE

See also articles "Jewellery Industry", "Gold Mines" and "Watch and Clock Makers".

Gilding workrooms, in particular workrooms where gilding and gilding on metal are carried on, should be well lighted and maintained in a state of absolute cleanliness. The floor should be impermeable and thoroughly cleaned by the wet method. Measures should be taken to ensure that all harmful and disagreeable emanations are withdrawn and not allowed to incommode the workers. Harmful emanations such as those from acid waste water should not be discharged outside until they have been submitted to neutralisation or other adequate treatment.

Scouring and mercury gilding should be executed under a closed hood with an active draught. In the case of gilding, a hood with a movable cover should be placed over the amalgamation and volatilisation furnace. The galvanic cells and the dipping vats should also be placed under hoods.

During gilding on wood, the most appropriate methods should be obtained for reducing or eliminating harm likely to be caused by the substances handled. Measures of personal hygiene should be assured for all the workers, who should further be instructed in regard to the risks to which they are exposed.

LEGISLATION

Women are excluded from the polishing of precious metals (gold) in Argentina; young persons under eighteen years of age are excluded in France from the refining of gold and silver by acids (when harmful fumes are freely liberated and when use of acids is involved); boys under sixteen years of age and girls under twenty-one are excluded in Spain from operations of gold plating by the galvanoplastic method; boys under fifteen and women under twenty-one are excluded in Italy from the refining of precious metals, etc.

**Gold Mines**

French: Mines d'or. — German: Goldhütten. — Italian: Miniere d'Oro. — Spanish: Minas de Oro.

The gold mines of the Witwatersrand are situated in the Transvaal Province of the Union of South Africa. The shaft heads of all these mines are at an approximate elevation of 5,500 ft. above sea level. They are all deep level mines, the majority of the workers underground being employed at between 3,000 and 7,000 ft. below the surface. The deepest mines are therefore some 2,000 ft. below sea level. The limit of depth has not yet been reached, and shafts are in progress of being sunk to the 8,000 ft. level below the surface.

The mines employ approximately 188,000 natives of the Bantu races, a few hundred persons of mixed races, and some 21,000 Europeans. Most of these employees work underground, relatively few being employed in surface work, such as metallurgical processes, shops, etc.

TECHNICAL OPERATIONS

Practically all the mining is done by means of compressed air-driven drilling machines, mostly of the "jackhammer" type. Very little drilling is done by hand. The blasting is done by means of "gelignite". After being blasted, the rock is loaded into trucks, and some are conveyed to the shaft mostly by manual propulsion; relatively few mines have mechanical haulage, except on main haulage ways. The shovell
ing of the rock from the face and the propulsion of the vehicles carrying the rock constitute the heaviest physical labour normally done by the workers. This work is done entirely by natives.

**Sources of Risk**

No special interest attaches to the work done on the surface in connection with the extraction of gold. There were two dangers to health connected with this occupation, the second of which has practically disappeared (see also article "Gold"). The first is the danger of poisoning by cyanide, which, in the form of sodium cyanide, is used for dissolving the gold from the finely ground rock. The elaborate precautions taken and the fact that everyone is cognizant of the danger of cyanide make these accidents extremely rare. Years pass without a single accident due to this cause occurring.

Until some years ago (1920-1921) there were a certain number of cases with chronic and acute mercurial poisoning, due to workers handling mercury during two stages of the extraction. In the first stage the pulverised rock mixed with water was allowed to flow over inclined copper plates on which metallic mercury was spread, the gold amalgamating with the mercury, and the resulting amalgam being scraped off by hand; this process was in most cases accompanied by the heating of the plate by means of a steam jacket. The mercury thus came in contact with the hands of the workers, and also entered the body by inhalation. This method of amalgamation has now been almost entirely abolished. The gold is now caught on corduroy cloth and this cloth, together with all its gold content, is placed in contact with mercury in closed rotating cylinders. Thus the workers are not subjected to any extent to exposure to mercury.

There still remains the possibility of mercurial poisoning in connection with the heat treatment of the amalgam. To eliminate this danger the furnaces are now equipped with special mercury vapour ejectors, and the result has been the practical disappearance of mercurial poisoning due to this cause.

Owing to the great depths of the workings, the pressure on the exposed mined areas is naturally very great, resulting in detachment of fragments of rock, which sometimes give way with great violence, and also to ordinary falls of rock. These causes constitute a prolific source of injuries. Thus, for instance, in the seven months January to July 1928, 968 injuries with 105 deaths were due to this cause.

The next largest number of injuries, but not of so serious a nature, is due to moving vehicles underground. For the same period 908 cases of injury with 41 deaths were due to this cause.

Falling material of various kinds caused in the same period 903 injuries with 20 deaths. This includes all sundry falling objects other than falls of unsupported overhanging rock or rock extruded by pressure.

Constant improvement is taking place in the technique of supporting the mined areas and in the technique of mining, with a resulting decrease in the risk. Similarly, other sources of accident are constantly being investigated and dealt with by a standing Committee for the Prevention of Accidents, composed of representatives of the mining industry and the Government. The activities of this Committee can perhaps best be summarised by saying that, in spite of increase in the inherent risks of mining due to greatly increased average depth and introduction of machinery, the death rate from accidents has decreased from 3.81 per 1,000 in 1913 to 2.83 per 1,000 in 1927.

**Statistics**

There are no records of morbidity and mortality for European employees on the Witwatersrand gold mines which can be compiled satisfactorily for publication. For native employees the following are the figures for the principal causes:

<table>
<thead>
<tr>
<th></th>
<th>Morbidity (rate per 1,000 per annum)</th>
<th>Mortality (rate per 1,000 per annum)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1915</td>
<td>1917</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>39.20</td>
<td>39.84</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>11.78</td>
<td>6.44</td>
</tr>
<tr>
<td>Miners' rhinitis</td>
<td>1.84</td>
<td>0.9</td>
</tr>
<tr>
<td>Typhoid</td>
<td>3.34</td>
<td>4.04</td>
</tr>
<tr>
<td>Scoury</td>
<td>2.10</td>
<td>1.06</td>
</tr>
<tr>
<td>Meningitis</td>
<td>2.44</td>
<td>2.53</td>
</tr>
<tr>
<td>Other diseases</td>
<td>342.80</td>
<td>289.56</td>
</tr>
<tr>
<td>Total diseases</td>
<td>303.00</td>
<td>345.60</td>
</tr>
<tr>
<td>Accidents</td>
<td>273.84</td>
<td>398.75</td>
</tr>
</tbody>
</table>

No morbidity data prior to 1915 are available. The preceding figures are for one group of mines employing approximately 65,000 natives, and represent, therefore, a fair example for the whole of the mines. These are given because it is practically impossible to obtain similarly reliable figures for other mines.
The advantages of medical supervision of the workers becomes very evident if comparison is made between the mortality rate per 1,000 natives occupied in the gold mines with that for coal miners. The figures, which do not include accidents, are as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Coal mines</th>
<th>Gold mines</th>
</tr>
</thead>
<tbody>
<tr>
<td>1924</td>
<td>13.50</td>
<td>9.99</td>
</tr>
<tr>
<td>1925</td>
<td>14.19</td>
<td>8.61</td>
</tr>
<tr>
<td>1926</td>
<td>13.25</td>
<td>9.05</td>
</tr>
</tbody>
</table>

This difference is still more marked when the various causes of death are examined. The averages (per 1,000) for the period 1924-1926 are: 2.45 from pneumonia (coal miners 3.92); from influenza 0.57 (coal miners 1.10); miners’ phthisis 0.27 (coal miners 0.63); other respiratory diseases 0.18 (coal miners 0.66); circulatory diseases 0.43 (coal miners 0.92); diseases of the kidneys 0.26 (coal miners 0.57).

Special mention should be made of silicosis, which occurs with very pronounced incidence amongst workers in the gold mines. Thus, amongst the European workers in the Transvaal mines each year fresh cases occur, as may be seen from the following table (Watkins-Pitchford):

<table>
<thead>
<tr>
<th>Year following that in which simple silicosis has been reported</th>
<th>Patients affected with tuberculous silicosis</th>
<th>Total number of cases having developed into tuberculous silicosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st year</td>
<td>59</td>
<td>83</td>
</tr>
<tr>
<td>2nd year</td>
<td>83</td>
<td>138</td>
</tr>
<tr>
<td>3rd year</td>
<td>120</td>
<td>212</td>
</tr>
<tr>
<td>4th year</td>
<td>141</td>
<td>280</td>
</tr>
<tr>
<td>5th year</td>
<td>170</td>
<td>370</td>
</tr>
<tr>
<td>6th year</td>
<td>217</td>
<td>470</td>
</tr>
<tr>
<td>7th year</td>
<td>246</td>
<td>540</td>
</tr>
</tbody>
</table>

For the Kilo-Moto (Katanga) gold mines, statistical returns provide information relative to the distribution of the principal diseases treated in the hospitals in 1925. According to these statistics prepared by Daco (1926), the situation was as shown in the table in the next column.

### Pathology

Of all diseases, the most serious is pneumonia. During the year 1927, 3,372 cases of this disease were admitted to the native hospitals, with a case mortality of 12.29 per cent. for the year (402 deaths). It will be observed that the case mortality is rather low, but
the number of cases very high. Pneumonia holds first place among the causes of fatality from disease amongst the natives on the mines. The mortality rate per 1,000 in 1927 was 4.90 (Witwatersrand).

The natives are also very prone to tuberculosis. In 1927, 529 cases of pulmonary tuberculosis were admitted to the hospitals, with a case mortality of 11.72 per cent. for the year (62 deaths). Although this case mortality appears very low, it must be borne in mind that, under the law, it is compulsory to send to his home every native suffering from tuberculosis who is capable of travel, and as these cases receive compensation, they as a rule refuse to remain in the hospitals and undergo treatment.

Some 60 per cent. of natives recruited in Mozambique arrive on the mines in a state of ankylostoma, and about 20 per cent. of those recruited in South Africa. It is very rare, however, to find any clinical symptoms of the disease among these natives, and it also is noteworthy that the number of infected natives becomes less in proportion to the length of time they remain on the mines, i.e. there is apparently a spontaneous cure of a certain number of people during their period of employment. Nevertheless, natives admitted to hospitals are very frequently treated for ankylostoma whilst they are in hospital.

The outstanding occupational diseases of the workers in the gold mines is, however, silicosis (see article "Tuberculosis and Silicosis"). It may exist for long without being evident, constituting in this case what is called latent silicosis, and the apparent symptoms only developing at a moment when the worker is no longer engaged in the mines. This was notably so in the case of certain old miners who took part in the Great War and who showed no symptoms at the moment of quitting the mines, but revealed clinical symptoms on their return. The clinical symptoms of this disease vary according as to whether it is a question of simple silicosis or silicosis complicated by tuberculosis.

The native workers are relatively less subject to silicosis than European miners engaged in skilled work in the mines. Thus, in 1923-1924 silicosis was found to be about fifty-six times more frequent amongst Europeans than amongst natives. On the contrary, the latter are more frequently attacked by simple tuberculosis. The number of cases of this disease was 3.5 times more frequent amongst the natives than amongst the Europeans.

The reason for the relative scarcity of cases of silicosis amongst the natives is to be found in the shortness of the periods during which they are occupied in the mines (Watkins-Pitchford).

The problem of silicosis amongst Witwatersrand miners was made the subject of two important reports presented to the Congress on Occupational Diseases (Lyons, April 1929) by Drs. Mavrogordato and Irvine. For this problem, which it is not possible to summarise even briefly here, the reader is referred to those reports, which deal with the problem in all its details.

The majority of natives arriving on the mines suffer from vitamin deficiencies, particularly of the antiscorbutic vitamin. This is manifested by a tendency to haemorrhage from the gums and haemorrhagic effusions into joints and muscles, as well as tendency to ulceration at the site of slight injuries.

During the course of 1927, 32,752 natives were admitted to hospital on account of injuries received at their work. The severity of the injuries caused by accidents can be gauged by the fact that the case mortality for accidents in the hospitals was 1.04 per cent. for the year (342 deaths).

HYGIENE

As a preventive measure against the spread of ankylostoma infection underground, sodium chloride is sprinkled on the floors of latrines and put into the stercus buckets, and the seats and walls of the latrines are washed once a week with a 20 per cent. solution of sodium chloride. This method of disinfection has been adopted after investigations carried out by the Research Medical Officer, Dr. W. R. Fischer, and extensive trials have shown that it is entirely efficacious and much more reliable than any commercial disinfectant tried. Suitable latrines, with concrete floors, and portable latrines are provided.

In the prevention of miners' phthisis (silicosis with or without tuberculosis) reliance is being placed principally on the use of water and ventilation. It is provided by law that no drilling must be done with a dry drill, and all drilling, whether by hand or machine, must be accompanied by constant application of water. In the case of machine drilling, the water is applied through the hollow axis of the drill, through which water and air are fed in suitable proportions. In the process
of “collaring”, i.e. starting the drilling of a hole, the axially fed water is supplemented by playing a hose on the rock face. Prior to shovelling rock, or loading it into trucks, or disturbing it in any way, the rock is thoroughly saturated with water applied by means of a hose. The sides and roof of the mine are also constantly sprayed with water. Before blasting is started a curtain of water, atomised by means of compressed air, is placed between the area of blasting and the remainder of the mine, and is kept in operation until all fumes and dust have been washed out or dissipated.

Ventilation, of course, is also essential to reduce the high temperatures which prevail in the lower portions of the mines, especially in view of the fact that the air in all the Witwatersrand mines is saturated with moisture. To ensure the necessary ventilation mechanical means have to be adopted, which consist of fans on the surface, auxiliary fans and compressed air and Venturi tube injectors underground, with the necessary conduits. Dry and wet bulb thermometer, anemometer and kata-thermometer readings are regularly taken underground in various working places, as well as determination of CO₂ content. Fortunately, the Witwatersrand mines are naturally free from deleterious gases.

Personal hygiene. — Practically no control can be exercised over the personal hygiene of the Europeans once they are away from the mine. On the mine the following provisions are made:

Change houses, with lockers or other arrangements for storing clothes; wash basins and shower

Recognising that water will not lay the finest particles of dust, which are those causing silicosis, the use of water is supplemented by proper ventilation of a sufficient velocity to clear the air of any residual dust. This ventilation is specially intensified after blasting operations.

It must be here mentioned that blasting takes place after the bulk of the workers have been removed from the mine and after those engaged on blasting have reached a place where the dust caused by blasting cannot affect them. For this reason all blasting is done by means of time fuses.
baths, with hot and cold water; free coffee on coming off shift; various recreation facilities, such as club houses with reading rooms and billiard tables, tennis courts, swimming baths, golf links, bowling greens, etc. All games are encouraged and fostered.

Only a relatively small portion of Europeans reside on the mines. For those who do reside on the mines adequate housing accommodation with good sanitary and water services is provided.

All European miners are subjected to a semi-annual medical examination at the Government Medical Bureau, which includes a radiographic examination of the chest. No miner may be employed underground who has not been passed as fit by the Government Medical Bureau, and the severity of this examination may be gauged by the fact that approximately one-half of the applicants for the initial medical examination to start work in mines are rejected by the Bureau.

**Medical service for Europeans.** — The ordinary medical attendance on Europeans is carried out through the medium of Benefit Societies, of which all European employees on the mines are compulsorily members. These societies are supported by contributions made by the employees. In return for these contributions the employees receive the following principal benefits:

1. Half of their average earnings when incapacitated by sickness or injury,
2. Medical attendance for themselves and members of their families for either sickness or injury,
3. Medical attendance in connection with maternity,
4. Funeral expenses for the insured person and his family.

Medical attendance includes all medical and surgical needs, including maternity, and free hospital treatment as "paying patients," when required.

For the purpose of dealing with accidents arising underground, a very elaborate organisation has been built up. At the head of the organisation stands the Mine Medical Officer. Under him there is a Chief Ambulance Officer with Assistants in charge of various sections of the mine. Under the law, every official on the mine, beginning with the grade of Shift Boss, whose position corresponds with that of Foreman, must be in possession of a First-Aid Certificate issued by a recognised Society, which, in the case of the gold mines, is the South African Red Cross Society. In order to obtain such a certificate, it is necessary for them to undergo a course of lectures and demonstrations of approximately twenty-four hours, and then to undergo an examination in First-Aid to the Injured, with special reference to mining conditions. The certificates must be renewed triannually, after an examination as to competence.

The equipment for rendering first aid consists of having at various points in the mines, as well as at the shaft head, a metal box containing the necessary appliances, stretcher, blanket, etc.

All European workers as well as natives are encouraged to undergo training in first aid. In addition to those who are required by law to hold a certificate in first aid, quite a considerable proportion of other European employees and over 15,000 natives are in possession of such certificates. In order to stimulate interest in this work, periodical competitions are held between various sections of each mine and between various mines, and once a year a national competition is also held. At these competitions valuable cash prizes, as well as medals and trophies, are awarded.

**Hygiene and medical services to natives.** — In the case of natives applying for employment on the mines, they are first of all medically inspected by medical officers in various parts of the country, the natives applying to the nearest accredited medical officer. If passed by this officer, they are sent to a Central Depot in Johannesburg. At this Depot there is a staff of full-time medical officers, and the natives are subjected to a very thorough physical examination, whilst their clothes and other belongings are disinfected. If they pass this examination, which in many instances includes a radiographic examination of the chest, they are sent to the mines on which they choose to serve. Here they are examined by the mine medical officer with a view to determining their suitability for the particular class of work on which they are to be employed. Thereafter, during the period of employment, each native is examined at intervals of not more than six weeks in the following way:

He is weighed and inspected by a trained European. If his weight has fallen more than 5 lb. since the last examination, or if he otherwise appears to be "below par," he is set aside for examination by the medical officer.
It is part of the legal obligation of mine owners to provide the natives employed on the mines with free medical treatment for both diseases and injuries. The mine owners are obliged to provide hospital accommodation equivalent to 2½ per cent. of the average number of natives employed on the mine, and to appoint a sufficient number of full-time medical officers to provide medical attention to the satisfaction of the Minister of Mines.

The methods of one group of mines will serve as a fair example of how this requirement is dealt with in practice. This group has for their gold mines three Central Native Hospitals, with a total bed capacity of approximately 1,200; four other hospitals with a bed capacity of about 650, and seven mines three Central Native Hospitals, whose duty it is to attend to native workers, and natives employed on the mines with free medical treatment for both diseases and injuries. The mine owners are obliged to provide the natives employed on the mines with free medical treatment for both diseases and injuries.

The Central Hospitals are staffed by a subordinate medical personnel consisting of European trained nurses, native girls undergoing training as nurses, or already trained, and male European and native trained orderlies.

The four other Hospitals and the Dressing Stations are staffed with male European and native personnel only.

On returning from work every native is inspected by a native watchman, whose duty it is to ascertain whether the worker has any injury or sickness. If he has a minor injury, he is immediately conducted to an ambulance room, situated at the barracks entrance, where his injury is attended by a trained orderly, or, if the injury is considered too serious to receive ambulatory treatment, he is sent to the hospital.

In order to combat vitamin deficiency, the diet of natives has been specially arranged to include a maximum of anti-scorbutic vitamin.

A native's daily ration consists of the following ingredients and quantities:

<table>
<thead>
<tr>
<th>Articles</th>
<th>Minimum daily allowance</th>
<th>Energy value (calories)</th>
<th>Vitamins</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ozs.</td>
<td>2.568</td>
<td></td>
</tr>
<tr>
<td>Meat meal</td>
<td>24.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bread</td>
<td>6.00</td>
<td>441</td>
<td></td>
</tr>
<tr>
<td>Beans or peas</td>
<td>1.50</td>
<td>145</td>
<td>0</td>
</tr>
<tr>
<td>Ditto</td>
<td>1.50</td>
<td>145</td>
<td>+</td>
</tr>
<tr>
<td>Stemmed beans</td>
<td>1.50</td>
<td>145</td>
<td>+</td>
</tr>
<tr>
<td>Meat</td>
<td>6.82</td>
<td>470</td>
<td>+</td>
</tr>
<tr>
<td>Soup meat</td>
<td>1.70</td>
<td>145</td>
<td>+</td>
</tr>
<tr>
<td>Pea nuts</td>
<td>2.00</td>
<td>921</td>
<td></td>
</tr>
<tr>
<td>Sugar</td>
<td>1.00</td>
<td>116</td>
<td>0</td>
</tr>
<tr>
<td>Vegetables</td>
<td>5.00</td>
<td>80</td>
<td>0</td>
</tr>
<tr>
<td>Salt</td>
<td>0.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cocoa</td>
<td>0.35</td>
<td>34</td>
<td>0</td>
</tr>
<tr>
<td>Kaffir beer</td>
<td>0.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4,385</td>
<td></td>
</tr>
</tbody>
</table>

It will be observed that the principal sources of anti-scorbutic vitamin in this ration are vegetables and germinated pulses. In order to conserve as much as possible the anti-scorbutic value of these articles, the vegetables and pulses are placed in the cooking pots not more than forty minutes prior to distribution of the ration. As this period is insufficient properly to cook the pulses, ammonium carbonate is added to the water, in the proportion of 2½ oz. to 15 gallons of water. This amount leaves no taste whatever and serves to cook the pulses in a satisfactory manner.

Since the introduction of the present ration and the method of cooking, scurvy, from being one of the most important factors of disability and death, has been reduced to negligible proportions.

In connection with scurvy, it might be of interest to record that in severe cases it has been found that the most efficacious treatment is intravenous injection of fresh orange juice, neutralised with sodium hydroxide. The dose used is 20 c.c. to 30 c.c. every second or third day. Two or three doses are invariably sufficient to cure even obstinate cases, such as those of severe haemorrhages to the knee joints, with contractures, etc., or severe ulcerations of the legs.

The method of preparation of the orange juice consists in cutting an orange in half with a sterile knife, squeezing the juice out with a sterile squeezer, filtering it first through gauze and then through filter paper, and then
neutralising to litmus paper with decinormal sodium hydroxide. The juice is injected slowly into a vein at the arm.

The native force employed on the mines has an average turnover of over 100 per cent. per annum. The mine labourers do not bring their wives and families with them. They are housed in barracks, in rooms holding between ten and fifty persons. Recently there has been a tendency to make the rooms of the smaller size. It is the recent practice to arrange the sleeping accommodation in such a way that there is a solid partition between each sleeper and his neighbours, the internal arrangement of the modern barrack rooms being analogous to those in an ordinary ship's cabin, i.e. the bunks being arranged in two tiers. Approximately 250 cub. ft. of air space is allowed for each occupant, and sufficient permanent ventilation openings are provided to ensure a proper interchange of air without creating draughts. The modern barrack room as evolved from numerous preceding types has proved entirely satisfactory from the hygienic point of view.

Central Rescue Training Station.—Although no noxious gases are produced in the mining operations in the gold mines, there are occasions such as fires, the accidental ignition of explosives, etc., which require the employment of persons trained in the use of oxygen-breathing rescue apparatus. There has been established therefore a training station where certain selected employees are trained in the use of such apparatus. The apparatus used is the "Proto".

The station is in charge of a specially trained superintendent, who, in addition to his duties as trainer, periodically visits all the mines to inspect the apparatus and familiarise himself with the ventilation and other plans of the mine, so as to be in a position to take charge should the emergency arise.

Legislation

The special legislation applying to the South African gold mines consists of an elaborate code of mining regulations, which aims principally at imposing regulations in the interests of safety. The outstanding features of these regulations are:

1. That all miners must be in possession of a certificate as to competency granted after examination.

2. That all officials must be in possession of Government certificates entitling them to hold appointments in the various grades.

3. That no native or coloured persons may be placed in charge of certain classes of machinery.

4. That certain ventilation standards must be maintained, and that water must be used in all operations which are liable to create dust.

The ordinary Workmen's Compensation legislation in regard to injuries and occupational diseases of course applies to the mines, but in addition there is in existence a special Act dealing with miner's phthisis (silicosis with or without tuberculosis), and with pure tuberculosis. The outstanding features of this special legislation are as follows:

No person having tuberculosis is allowed to be employed underground or in certain occupations on the surface of the mines. It is a penal offence for the sufferer from tuberculosis to continue at work, and it is a penal offence for the mine management to employ such a man. When a person is notified as suffering from tuberculosis, he must be immediately retired from service, and he is paid a compensation based on his earnings. This takes the form of a lump sum, which, in the case of natives, averages approximately £250 and, in the case of Europeans, approximately £500.

Silicosis without tuberculosis in its earliest detectable stage, which is legally known as "ante-primary", is compensated by a lump sum based on earnings, which, in the case of Europeans, averages approximately £35 per annum, and in the case of natives, approximately £30 per annum.

In its next stage, legally known as "primary", the lump sum award is on the same basis as for tuberculosis.

In the next, more advanced stage, legally known as "secondary", the European miners are granted a life pension, calculated on the basis of earnings and further modified by the number of dependants. Native miners receive a lump sum of twice that granted for the primary stage.

The average pension for an ordinary miner earning £30 a month, with a wife and two minor children, would be approximately £18 per month.

All compensations payable under this Act are transferable to the dependants of the miner on his decease.

A special Board is set up to administer this Act, and this Board has large discretionary powers in the way of aiding the rehabilitation of beneficiaries by means of loans to industries undertaking to employ such people, or by means of establishing agricultural settlements, etc. This Board also assesses the liability of each mine in respect of the current and outstanding payments, and this levy is payable direct to the Board and constitutes a first charge on the mine's assets. Provision is also made for recovery of the sum due from any mine in respect of estimated outstanding liabilities, which be-
comes a first charge on the mine's assets in the event of the mine closing down. See article "Building Trade", Legislation, South Africa.

Bibliography


Dr. A. J. Orenstein (Johannesburg).

Graphite

(Plumbago)


Natural graphite is a kind of carbon found in nature in a crystallised state in the form of sheets of hexagonal slabs and sometimes in brilliant amorphous masses which break off in sheets.

Graphite, which is greyish-black in colour, is a fusible substance, a conductor of heat and electricity and is resistant to certain acids; with fuming nitric acid, for example, the graphite swells, turns red and takes the form of a kind of Pharaoh's serpent.

The oldest mines are those of Borrowdale (England), but the richest are those of Truktsch, Austria, Czechoslovakia, the United States, Mexico, Italy, etc. The most important mines in the world, however, are those of Ceylon, which give work to several tens of thousands of workers.

The extraction of graphite in Ceylon is effected by the natives in a primitive manner. The material extracted from the pits is subjected to hand sorting, with a view to extracting the best pieces; the remainder is simply levigated with water, which removes outside impurities consisting of clay, oxide of iron, pyrites, silica, etc. A second-hand sorting process achieves suppression of the larger pieces, and the remainder is classified in several sizes by means of metal frames. It is then put in barrels and exported.

In other districts the graphite which is more mature is subjected to mechanical sorting (a surer method) and eventually to chemical purification after grinding. There is utilised for this purpose molten caustic soda and finally hydrochloric acid and water. Other processes involve the use of petroleum and hot water, with powdered carbonate of calcium; dilute hydrochloric acid is added and the mixture is then stirred. The carbon dioxide liberated brings the finest particles of graphite to the surface. Should the graphite contain resistant silicates it is treated with sulphuric acid and ammonia fluoride; hydrofluoric acid is given off, which combines with the silica to form silicon fluoride in a gaseous state capable of regenerating ammonium fluoride when bubbled through ammonia. Whilst formerly almost the entire output of graphite was utilised in the manufacture of pencils, in the last thirty years, though the production of pencils has increased a hundredfold, only 4 per cent. of the total production of graphite serves this purpose. The greater part to-day is used for the manufacture of crucibles for the fusion of metals and metallic alloys, and especially for the manufacture of large electrodes for electric furnaces and of carbons for arc lamps, etc.

Very finely powdered graphite (plumbago) is utilised as a coating or varnishing medium for the preservation of iron and cast iron from rust. It is also applied cold in the form of a colloidal solution to protect steam generators and their hearths (as graphite acts as an anti-adherent).

Graphite for lubricating purposes must be in very finely powdered form. Powdered graphite is treated with chlorate of potassium and concentrated sulphuric acid, the resulting mass is cooled, thoroughly washed with water, dried and made red hot. Other processes involve treatment of the graphite with concentrated nitric acid, bringing it to red heat, while recuperating the acid, separating out the pure graphite which is then washed, levigated and compressed in ribbon form.

Artificial graphite is prepared in large quantities by means of the Acheson process, from which it is obtained as a secondary product in the preparation of silicon graphite ("carborundum") by using as carbon petroleum coke mixed
with pitch, silica or oxide of iron. When graphite is required for colours or for crucibles, anthracite carbon is employed.

It can also be got by causing acetylene mixed with carbon monoxide and carbon dioxide to pass into a red-hot tube or over red-hot calcium carbide.

Data relative to the occupational pathology due to graphite are almost non-existent. In fact, only one single case of graphitosis is known, having been described by H. Koopmann in 1924. The case was one of pure pneumoconiosis with pulmonary cavities but without traces of tubercular lesion in a man sixty-eight years age, who died as the result of an industrial accident (fracture of the base of the skull) and who for fifty years had been engaged in grinding graphite.

The post-mortem examination showed that graphite was only present in the parenchymatous organs in very minute quantities. This pneumoconiosis due to graphite was characterised by development of long duration and by minor troubles. It may be stated that graphitosis belongs to the harmless class of pneumoconioses. Like all pneumoconiosis, it affects principally the middle region of the lungs and thereafter the upper rather than the lower lobes. In the case cited by Koopmann, diagnosis was only possible with the use of X-rays.

The pulmonary modifications brought about by continuous inhalation of graphite consist in a chronic interstitial pneumonia with peribronchiolitis and chronic or nodulous periarteritis and occlusion of the blood or lymphatic channels, followed by tissue necrosis.

During the evolution of the pneumoconiosis there occurs hypertrophy of the right ventricle of the heart, diagnosis of which seems highly important in distinguishing intra vitam between pneumoconiosis and pulmonary tuberculosis.

If a conclusion may be drawn from a single case, it may be said that graphite pneumoconiosis does not appear to cause predisposition to pulmonary tuberculosis.

The enquiry carried out by Hollmann among the workers in a lead pencil factory exposed to graphite and carbon dust only revealed 3 cases of pneumoconiosis, which could be accurately detected amongst 33 workers engaged in the industry for upwards of five years. The workers in question had been engaged in the industry from 6-10, 21-25, and 36-40 years. Amongst the other workers 16 were found to be in the early stages of pneumoconiosis, 19 suffering from bronchitis and emphysema but without pneumoconiosis. Lesions of a distinctly tubercular nature were only met with in four cases.

The other pathological data available are only related to the use of graphite in the various industries mentioned above, in which the sources of the injury were, however, represented by other substances utilised in the course of industrial manipulation (lead, acids, nitro and amino derivatives, etc.).

As regards legislation it should be recalled that in Italy boys under fifteen and girls under twenty-one years of age are excluded from graphite factories when dust is liberated freely unless diffusion is prevented in an effective manner.

**BIBLIOGRAPHY**


Hair


Human hair as placed on the market is first sorted according to colour and length (30 to 100 centimetres), the commercial value depending chiefly on these two qualities. Japanese and Chinese hair, though fairly long, is of less value than that coming from other countries. Red hair or hair varying in shade is usually coloured a darker tint. Hair from corpses has little value because it is easily broken. Combings are likewise of little value.

Very little data is available in medical literature relative to hygiene or pathology in the hair industry, which is nevertheless fairly highly developed in China, Italy and in Southern France. On the basis of an enquiry effected in Italy by Professor Loriga (1910 and 1915), it is possible to assemble here information concerning the handling of hair engaged in, not only by hairdressers, but also by specially trained workers in laboratories set apart for this purpose — Southern Italy, for instance, where Carapelle had already carried out an enquiry, limited however to the town of Palermo.

The Italian industrial census of 1910 showed 172 laboratories giving occupation to 1,390 persons, of which 913 were young females. More recently (1921-1922), Teley has also had an opportunity of studying this industry in the Düsseldorf district, and in his report for the year in question he describes in detail the technical data and the detrimental effects of handling and selling hair. Hair, which generally arrives plaited, is first of all opened out, then follows cleaning by means of flour or talc in order to facilitate handling. The hair is then rendered free from grease by means of a soda or potash solution (30 per cent.) or of soap. It is then dried.

The handling of human hair may give rise to such diseases as, for example, *achorion Schonleini* and *trichophyton tonsurans*, etc. The hair may have been infected for a long time by the spores of these human fungoid parasites, and constitutes a propagating agent for other infections such as eczema, boils, smallpox, scarlet fever, etc. In hairbrushes which have been used by tubercular patients, the tuberculosis bacillus has been found.

In 1895 Renon described two cases of pulmonary aspergillosis due to mould from rye bran used for removing grease from hair. Laboratory animals (birds) died from the effects at the end of two to three months.

It must, however, be recalled that the capacity for infection of the germs present in hair is attenuated or rendered nil very rapidly when not under favourable conditions of development, and that besides certain causes may be said to be very exceptional or quite accidental in their occurrence.

Practically speaking, the danger of contamination is limited to such parasites as *tinea*, *herpes*, *staphylococcus* from eczema and furunculosis, diphtheria, tuberculosis and typhoid bacilli, and to parasites such as *pediculus capitis*.

It is obvious that hair should be freed from such pathogenic germs and such parasites before workers are required to handle it in making plaits, curls and switches, etc. This object cannot, however, be attained except by disinfection.

Since it is a question of surface infection, it might be thought that mechanical cleaning by means of beating and drying under pressure would be sufficient. Practice has however demonstrated this method to be costly and inapplicable since greasy matter adhering to the hair prevents its successful adoption. Dry cleaning by means of bran, starch or talc represents a very good method where it can be applied prior to any other operation and
HAIR

918

eflected in closed apparatus or under a ventilation hood with adequate dust removal by exhaust apparatus.

The operation of undoing the hair is delicate and difficult of execution under exhaust ventilation. For this reason it is essential to disinfect the hair the moment it arrives at the laboratory before any other operation is engaged in. Loriga has proposed the adoption of simple boiling for five minutes, since other disinfection processes such as permanganate of potash might alter the colour of the hair. On the other hand, it is necessary to follow a simple method which does not interfere with the strength and elasticity of the hair. A temperature of 80° to 100° C. should suffice to kill the hyphomycetae spores, for in this industry it is not necessary to reach the limits required for disinfection of other products (animal hair, wool, etc. — anthrax spores!).

The hair is then cooled and dried. Another method to be recommended is that of disinfection by means of formaldehyde fumes. On the other hand, the use of a hot carbonate of soda solution (10 per cent.) is not to be recommended, because it is extremely difficult to comb out the hair afterwards. Certain manufacturers have suggested sulphur, creoline, or denatured alcohol at 40 to 50 per cent., a sublimated solution of anisodol (an aqueous solution at 1 per cent. of paraformaldehyde with an allylic series derivative and a little glycerine) which is said to be used successfully in Naples and in France.

It must be stated that certain of these methods are not advisable by reason of the fact that they interfere with the colour, strength and elasticity of the hair or again because the fumes penetrate with difficulty the very tightly packed rolls of hair.

It is obvious that under the circumstances disinfection must be applied with every precaution essential to ensuring satisfactory results.

In Italy a Government Circular of the Ministry of Agriculture, Industry and Commerce in 1910 laid down that in the hair industry women under age and children might not be employed unless the hair had been previously submitted to disinfection. This order left the employer free to choose the method of disinfection to be adopted, provided, however, that the latter was recognised as effective by the Ministry. Boiling in water for five minutes was recommended.

In Germany the Labour Code forbids the house-to-house collection of hair sometimes engaged in.

Home work on hair which has not been previously disinfected ought to be prohibited, and in workshops where hair is handled the installation of a separate room for disinfection purposes should be required. (See also articles "Hairdressers" and "Occupational Diseases: Skin").

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Hair Cutting

(Hatters Furriers' Processes)


Hatters furriers' processes have for their object the preparation of hair intended for hats (see article "Felt Hat Industry"). At the same time, while hatters' furriers' processes in the literal sense include the greater part of the operations, the term is very often limited to only a section of the processes in the manufacture of hats, namely, those workshops where a few preliminary operations are carried on.

RAW MATERIAL

Generally rabbit skins or skins of hares arrive dry, without any kind of preparation; occasionally dressed with naphtha (and conceivably arsenic). They are sorted and classed according to colour, size, and quality.

Warehouses for skins, clippings and parings, tails or hair require to be well ventilated, kept clean and separate from living rooms or workrooms where the materials are handled (Belgian and French Decrees). There should be ventilating shafts reaching above the roof; the walls and ceiling should be lime-washed at least once a year; clippings and waste should be placed in a covered receptacle, to be disinfected, if necessary, and removed at least once a week. (See article "Odours").

PRELIMINARY PROCESSES

Opening of the skins along the ventral aspect; cutting along their whole length; cutting off the ears, heads, paws, and tails; stretching the skins to remove folds; at times rubbing the hairs the wrong way with a special tool (blunt, triangular knife, of which the point is fixed in a massive handle); and, finally, cleaning with a special blunt toothed knife.

The opened skins are at times brushed with a wire brush and, even before any other operation, washed. If this is done, the waste water should be carried directly out of the workroom
and poured into a closed drain because the water, rich in organic matter, gives rise to unpleasant smells and is full of bacteria from the surface of the skin.

Pulling consists in extracting from the skin, by means of a slightly sharpened knife, the hard hairs refractory to pulling, which fall into a trough placed on the table of the worker. If the skin is not suitable for pulling, it is subjected to clipping, which consists in shaving off long hard or exuviant hairs with scissors, but leaving the sound hairs intact. These

Women do this work almost exclusively, often in their homes.

Pathology. According to the Belgian enquiries, although generally in good health, the persons employed in Processes anterior to carcinising, suffer from irritating lesions of the nasal fossae, hypertrophic or ulcerating rhinitis, frequent small ulcers, very tiresome and sufficiently painful, more rarely of the pharynx; inflammation of the turbinal bones, eyelids (slight degrees are very common), of the carotid externa, and of the skin.
knives, but subsequent sepsis is very rare.

The particular occupational posture of the fur pullers, associated as it is with rapid repetition of the same movements, is said to act injuriously on health. Complaints of neuralgia, lumbar curvature are common, and might seriously affect women at the time of confinement. There also occur hypertrophy of the muscles of the right arm, especially of the biceps, and inflammation of the tendon sheaths of the forearm (relatively common). The troubles caused by the action of pushing the machine with the base of the thorax or abdomen, especially in the case of women, may easily be avoided, for in the best machines this movement is done by means of a pedal lever.
Hygiene. — Introduction into the workrooms of more skins and hair than is wanted for a day's work should be prohibited.

Where locally applied exhaust ventilation for the removal of dust is not provided, the apertures of these workrooms should be provided with metal shutters.

**Carotting, properly so called**

Carotting is the operation of wetting the rabbit fur with a solution of acid in the amount of free acid. Formerly, the solution was prepared in the factory, but nowadays the occupier prefers to buy it and to dilute it to the strength necessary for the several qualities of skins.

The two usual formulas are the following:

- **Yellow carotting.** Mercury: 5 kg.; nitric acid (at 40° B.): 25 kg.
- **White carotting.** Mercury: 8 kg.; nitric acid (at 40° B.): 25 kg.

Other formulas for a white carotting solution give the nitric acid at 36° B.

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**Fig. 155. — Carotter's bench with exhaust system for acid fumes: supper horizontal cover.**

A solution of mercury in nitric acid is spoken of as the "secret." This "secret" solution, of French origin, dates from the commencement of the seventeenth century, and was introduced into England by persons expatriated by the revocation of the Edict of Nantes, 1685. A French workman, Mathieu, returning from England in 1747-1748, gave away the "secret" to his companions in Paris.

Each factory has its own particular formula and varies the strength of the mercury, which results in differences in the chemical reaction is as follows:

\[
\text{HN \cdot 3 Hg = 3 (HgO) + 3 H_2O = 2 N_2O} + \frac{92}{1104} + \frac{108}{1104}
\]

Eight molecules of mono-hydrated nitric acid are necessary to dissolve three molecules of mercury; in the mercuric nitrate obtained there remain only the elements of six molecules of nitric acid. Two molecules are therefore destroyed to furnish the oxygen to the mercury, and a gaseous residue of dioxide of nitrogen escapes into the atmosphere and, on contact with the
air, becomes converted into peroxide of nitrogen or hyponitric acid and gives off red fumes (see article "Nitrous Fumes").

The skin to be carotted is spread out on a sheet of slate and kept in position by means of a short stick — sometimes by the fingers specially protected. The solution is applied to the fur side by means of a brush and the fur is brushed in the direction of the hair.

The introduction of carotting machines, although they do not appear to be of great use to the worker who does the carotting, represents a great step so far as the healthiness of the work is concerned, because they notably reduce the number of persons exposed to danger. One machine is said to do the work of from six to nine persons.

In general, these machines, of which there are several types, substitute for the ordinary brush a rapidly revolving cylindrical brush against which the workman (with his forearm protected by rubber gloves) presents the skin to be carotted. While the local action of the secret solution on the skin is less frequent with machine carotting, the atmosphere of the workrooms, according to some investigators, contains more acid even than that of workrooms where carotting was done by hand. Still, it is possible to improve the machine at present in use by more effective localised ventilation.

Dangers. — Solution of the metallic mercury in nitric acid makes the carotting fluid evolve nitrous fumes, the action of which is so well known that all necessary precautions are generally taken. The presence in the fluid of a certain amount of arsenious acid is not proved.

Intermittent inhalation of small quantities of nitrous fumes is frequent, as they are given off as the brushed skins are moved from the tables, wet with the solution.

It is worth recalling that evaporation from acid solution of nitrate of mercury in a still atmosphere does not carry with it a particle of the metal. Even passing air slowly into a solution of nitrate of mercury does not carry away mercury, and search for the metal is negative even if made under a carotting table.

Pathology. — The external skin (of the hand and wrist) may represent a channel of absorption for the metallic salt solution, as they are often more or less deeply fissured.

Although real, this channel is at any rate unimportant. The skins are impregnated with the metallic salt, and, in the absence of cleanliness, a remote risk of intoxication by the alimentary tract is conceivable; but in practice the workman is on his guard against the caustic action of the acid solution, and, further, the epidermis of the horny hand in the stratum corneum possesses a layer very resistant to the introduction of mercury, more especially as the nitrate forms, with the keratin, a very stable organic combination.

The teeth of carotters are characteristic, partly owing to mercurial absorption in the system and consequent nutritional defect in the dental pulp, but principally through the progressive erosion of the enamel from incessant contact of the acid particles inhaled, and the formation of fermentation of black hydrogen sulphide. Hence the black colour of the teeth of carotters. Tremor and loss of teeth, without obvious stomatitis, also occurs (Koelsch).

Hygiene. — Preparation of the carotting fluid ought to be carried out in such a way that no nitrous fumes are inhaled by the worker. The addition of mercury to the acid can be done outside the stove by means of a funnel arranged syphon-wise or under a hood for fermentation of black hydrogen sulphide. Hence the black colour of the teeth of carotters.

A Decree of the Council of Hygiene of the Department of the Seine prohibited in 1892 the preparation of the carotting fluid in the factory, but this Decree has been treated as a dead letter. The operation, however, is dealt with in the Decree of October 1913, which, as is the case with the Belgian Decree, prescribes that the preparation of the nitrate shall be carried out in such a way that acid fumes shall not be inhaled by the workers, that in carotting the fumes shall be drawn away by locally applied mechanical ventilation as near as possible to the point of origin, that the wall surfaces to man's height, the ground, and tables for carotting should be impermeable (to nitrate of mercury) and swilled with water at least once a week. (Similar regulations are in force in the following countries: Belgium, France, Germany, the Netherlands, and the State of Missouri).

The liquid acid nitrate, which drops from the skins, brushes and tables, should be collected in receptacles. The acid and effluent should be deprived of all trace of mercury before their discharge in a closed channel into running water, or preferably into a sewer.
In the United States, preparation of the acid nitrate in drying stoves is prohibited.

**Stoving**

The skins are placed skin to skin in yellow, and fur to fur in white, carotting, then hung on long iron rods for treatment in the stove — a small closed room, in the middle of which a brazier is generally lit. The temperature rises quickly, and the atmosphere soon becomes a reducing one, owing to mercury, during the time of filling, and especially when emptying, fire.

No reduction of mercury salts takes place in the stove, nor is there mechanical removal of mercury vapour, but numerous toxic particles, which are far from being in stable organic combination, escape from the skin.

Open braziers are not absolutely indispensable for good results, as has been asserted; prolonged experience has shown that heating with pipes and radiators gives results identical with those of stoves of the old model.

The skins remain hung up for a certain number of hours 1 or 1½ to 10 or 12, generally from the evening to the morning.

**Dangers.** — High temperature (50-70° C.); gases (small traces of oxide of carbon given off from the brazier; according to Heim, there are only about 6 parts per 10,000, owing to the fair draught in the stoves); acid fumes (fusious fumes; according to Heim, about 250 c.c. per cubic metre); toxic dust (dust as the vehicle for carrying the emanations of the coke burnt. The skins should be hung up for a sufficient number of hours 1 or 1½ to 10 or 12, generally from the evening to the morning.

**Hygiene.** — The stove should not be in direct communication with the workrooms, especially if it is heated by braziers and if adequate measures have not been taken to prevent the spread of toxic vapours into the workrooms. The workers should never enter an insufficiently ventilated stove; arrangements should be made to hang up and withdraw the skins from the stove without the workers having to enter them (Germany, Belgium).

Tunnel drying stoves of small diameter, with trolleys on rails, allow of filling and emptying from outside.
The antiquated methods of stoving should be prohibited, and as a minimum in the way of precautions the actual stove should be surmounted by a metal hood to carry the burnt gas and acid fumes outside; this hood should be movable in such a way that the workman can lower it from outside before going into the stove.

BRUSHING

The skins, after being damped to make the pelt supple, are brushed energetically in order to separate the hairs which have stuck together in their passage through the stove. This operation is sometimes done by hand. It is the most unhealthy of all the processes because during this process a large part of the toxic dust which had been glued down in between the hairs is liberated.

To-day brushing is done almost exclusively by a machine in a closed apparatus, with localised ventilation to carry away the dust. This method, technically easy of accomplishment, is required in German and Belgian legislation. The health of the workers in this process is generally poor.

Dangers. — After carotting the mercury forms, with the keratin of the hairs, an organic compound which, while insoluble in water, becomes readily soluble in the human body. Harris (U.S.A.) has found the hair to contain 0.939 per cent. by weight of mercury in combination (organic combination with the keratin) and 0.662 per cent. by weight of uncombined mercury (in the form of metallic mercury or its salts), which would be proportionately greater if the examinations were made on the skins immediately after removal from the stove, as the later operations remove from the fur a considerable quantity of dust.

In a cutting room, out of a total of 75 milligrams of mercury, 42 milligrams have been found in a state of dust. Even in workrooms where machine brushing was done, 75 milligrams of mixed dust per cubic metre of air was found (Hebert and Heim). The danger is especially great in the cleaning of the brushing machines.

CUTTING

The brushed skins, after remaining several hours (or even months) in the cellar or store (in order to complete the felting and obtain a change in colour to brownish grey which is much in demand), next pass to the cutting machines, special machines which separate the fur from the pelt. Under the action of the cutting knives, the skin is shredded off (so as to resemble vermelli) and the mass of fur that is freed is folded into the form of a ball and packed ready for despatch to the next process — that of blowing. The "vermelli" is sent to glue factories (where it might give rise to mercurial poisoning).

Dangers. — Dust is given off from the cutting machines. These are more difficult to ventilate satisfactorily than the brushes, because, if the ventilation were too energetic, particles of fur might be carried away with the dust.

The cutting of the tails and small pieces also exposes the workers to poisoning. This branch is particularly unhealthy, and very difficult to safeguard. Mechanical processes have not become general, because of the small output.

Hygiene. — All workrooms where the work of cutting is done should be provided with good mechanical ventilation. At the moment there is no effective method of localised ventilation for cutting machines; as a consequence these rooms must be regarded as unsatisfactory, and the personnel should be submitted to careful medical supervision.

BLOWING

Blowing, the last operation of the cutting and the first of hat making (see article "Felt Hat Industry"), consists in separating the coarse from the fine fur. As far as possible the mixture as homogeneous a mixture as possible in the machine, in the interior of which cards revolve fairly slowly. After having been made to "fly" in the machine, the hair deposited on the apron is carried to the other end of the apparatus and leaves as a mass intimately mixed and of a uniform grey shade.

Dangers. — Poisoning from particles in suspension in the air. Persons engaged in blowing are more exposed to danger than those in cutting, because while the object of the latter is to keep the fur together, theirs is, on the contrary, to spread it on the travelling apron which carries it into the blowing machine.

Biot, of Brussels, states that the dust liberates mercury vapour.

Hygiene. — Complete hooding of the machines and discharge direct to the outside air of that which has passed
through the blowing machine is exacted by the Belgian Decree, section 11.

STATISTICS

No enquiry has been made in Germany. In 1922, however, Moeller examined 32 carotters, and found 25 per cent. with mercurial stomatitis (decayed or lost teeth, localised stomatitis, especially of the mucous membrane below the incisors). In Austria poisoning is said to be very rare. In Belgium, careful enquiry was made before the war by the Medical Inspector of Factories. At the time of the enquiry there were 32 premises engaged in hatters furriers' processes, employing about 968 persons, and 10 fur cutting workshops, with 1,235 persons employed. This population was distributed thus:

<table>
<thead>
<tr>
<th>Group of operations</th>
<th>Persons employed</th>
</tr>
</thead>
<tbody>
<tr>
<td>furriers' processes</td>
<td>968</td>
</tr>
<tr>
<td>fur cutting workshops</td>
<td>1,235</td>
</tr>
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<td>3,203</td>
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<td>Total</td>
<td>3,203</td>
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</table>

Grouped according to age, 71.92 per cent. of the men were between 20 and 30 years, and 31.98 per cent. between 31 and 40 years; 84.92 per cent. of the women were between 20 and 30 years, and 10.76 per cent. between 31 and 40 years.

While the health of the male personnel seemed unaffected up to the age of 30, a change was noticeable later. Further, as regards the women, many leave towards their thirteenth year, which explains the limited number of comparatively youthful persons in unhealthy workshops.

If the persons with less than 5 years' duration of employment in hatters furriers' workshops are excluded, only 4 men out of 370 (1.06 per cent.) were found who had worked upwards of forty years.

In judging of the health of the personnel, distinction should be drawn between those employed in processes previous to carotting, and those in processes subsequent thereto. Relative standards as judged by medical examination in these cases are as follows:

<table>
<thead>
<tr>
<th>State of health</th>
<th>good</th>
<th>medium</th>
<th>bad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>previous to pulling</td>
<td>98.91</td>
<td>7.90</td>
<td>0.28</td>
</tr>
<tr>
<td>Process of carotting</td>
<td>63.64</td>
<td>31.82</td>
<td>4.54</td>
</tr>
<tr>
<td>farther processes (brushing, cutting, blowing, various)</td>
<td>77.97</td>
<td>22.73</td>
<td>—</td>
</tr>
</tbody>
</table>

Medical examination showed conjunctivitis or blepharitis in 6.4 per cent. of the men in the fur pulling workrooms (4.7 per cent. of the women), skin affections in 0.7 per cent. of the men (1.9 per cent. of the women), respiratory affections in 0.4 per cent. of the men, and lateral curvature of the spine in 0.4 per cent. of the men (1.2 per cent. of the women).

Mercurial poisoning is particularly frequent among the blowers.

The enquiry showed that 66.67 per cent. of the men had signs of mercurial poisoning, 61.9 per cent. tremor, 11.12 per cent. stomatitis, 9.5 per cent. anaemia, and that the morbidity figures among carotters were very high. At the same time, the symptoms do not indicate that the workmen in question were in a bad state of health, for 57.49 per cent. of the men showing these signs of intoxication were classed as in good general health. Among the women, tremor or stomatitis was present in about 45 per cent. of those examined, while approximately 40-50 per cent. showed symptoms of mercury poisoning.

Striking, also, are the results of the enquiry as to the relation between the state of health, the risk of poisoning, and the hygienic conditions of the workrooms:

<table>
<thead>
<tr>
<th>Sanitation of workrooms</th>
<th>Good</th>
<th>Moderate</th>
<th>Bad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases of poisoning per 100 workers</td>
<td>37.21</td>
<td>56.25</td>
<td>88.89</td>
</tr>
</tbody>
</table>

The results of medical examination of the personnel during the years 1921 and 1925 were as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of premises inspected</th>
<th>Number of workers examined</th>
<th>Number of suspected cases of poisoning</th>
<th>Number of workers showing definite symptoms</th>
<th>Number of persons not affected, but in bad general health</th>
</tr>
</thead>
<tbody>
<tr>
<td>1921</td>
<td>First half-year</td>
<td>37</td>
<td>388</td>
<td>19</td>
<td>Male   19; Female 64</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Male 22; Female 23</td>
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<td></td>
<td></td>
<td></td>
<td>Male 32; Female 44</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Male 17; Female 40</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td>Male 2; Female 2</td>
<td></td>
</tr>
<tr>
<td>1925</td>
<td>First half-year</td>
<td>50</td>
<td>425</td>
<td>6</td>
<td>Male 23; Female 92</td>
</tr>
<tr>
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<td>Male 33; Female 87</td>
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<tr>
<td>1923</td>
<td></td>
<td>47</td>
<td>450</td>
<td>13</td>
<td>Male 45; Female 87</td>
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<td></td>
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<td>Male 32; Female 87</td>
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In France, 60 per cent. of the trade union workers showed symptoms, and the annual mortality from mercurialism was from 2 to 3 per cent. (Marshall, Paris, 1909). The danger from mercury is about the same for the persons employed in brushing, cutting, etc. (Heim, Paris, 1909), but it should be borne in mind that severe cases escape all record taken in the factory. Of the workers employed 51 per cent. showed
Fig. 159. — Red wild rabbit (soft fur). (Slightly enlarged.)

Fig. 160. — Red wild rabbit, white carotting. (Slightly enlarged.)

Fig. 161. — Carotting with nitric acid (head fur). (Slightly enlarged.)

Fig. 162. — Carotting with nitric acid (tail fur). (Slightly enlarged.)

Fig. 163. — Nutria (soft fur). (Greatly enlarged.)

Fig. 164. — Nutria: medium carotting. (Greatly enlarged.)
signs of mercurialism, and 31 per cent. marked signs — a total of about 82 per cent, altogether (Hein).

From the month of June 1921 till the month of September 1922 there were only seven cases reported from Paris and its suburbs, affecting workers (men and women) belonging to two firms only. Bargeron (1923) quoting these figures holds that these seven serious cases may be taken to represent ten times the number, in view of the fact that there are in France 42 factories possessing 142 cutting machines. These seven cases are noted in the mercury poisoning statistics reported in accordance with the Act of 1919.

Between 1923 and 1925 17 cases of mercury poisoning were reported, 15 of which occurred amongst carotters.

In Italy, of 12 persons employed in carotting (enquiry by Monti, at Monza, Milan) 9 showed symptoms. In the United States, L. J. Harris (1915) found amongst 183 carotters only 17 in good health.

Ninety-one of the workers examined, despite precautions taken, showed symptoms of mercurialism: gums in a spongy condition, trembling; 76-77 carotters and cutters had black teeth. According to the enquiry held in Great Britain in 1898 severe cases were not numerous, but there were a certain number of cases with fatal issue. Of 30 carotters examined, 66-6 per cent. showed defects in the teeth, and 3-3 per cent. tremor; whilst of 81 workers employed in later operations, 33-3 per cent. only showed defective teeth and 21 per cent. tremor.

There are no recent data for cases of arsenic poisoning amongst workers in cutting factories where skins treated with arsenic soap (sodium or potassium arsenate) are used or handled.

**Symptoms**

Mercurialism in carotters shows certain differences from ordinary mercurial poisoning (see article "Mercury"). It develops very slowly (except in rare cases), because the individual is exposed for long periods to small quantities of mercury.

The symptoms vary according to the duration of employment and the sanitation of the workroom.

Salivation is not, or very rarely, seen; on the other hand, those suffering complain of dryness of the mouth and throat. Mention has already been made of the teeth of the carotters as being as black as ebony, a condition which good dental toilet makes a little less pronounced. The upper teeth fall out early, and old workers are all edentulous. Those suffering from anaemia and weakness do not appear particularly predisposed to stomatitis. When the gums are swollen, a very narrow line is clearly seen at
HAIR CUTTING

the junction of the teeth, especially of the upper teeth. Some writers speak of the colour as grey, tending to blue or grey brown, or even café noir. Gilbert points out that it differs a little from the blue line in lead poisoning, by its tendency to be wider and by its more greyish tint. Often differentiation is difficult, because the two forms of intoxication may exist together or one after the other. The line is very rare in carotters, but more frequent in brushers, cutters, and blowers.

The lesions either of the nasal, laryngeal, respiratory, or conjunctival mucous membrane caused by the dust, have been mentioned. In most of the fur pullers running at the eyes is transient, but in a minority a chronic form of conjunctivitis is set up and, more rarely, stenosis of the lachrymal duct, attributable to an ascending infection, with dilatation of the sac and constant lachrymation. Topolski in 1894 described a rare form of keratitis in cutters, having the appearance of yellowish brown lines or rays made up of small points and layers. A hyperaesthesia of the cornea, and a very slight opacity has also been described, without interference with function.

The nitric acid sometimes causes dermatitis difficult to cure: an inflammation of the fingers, with rhagades round the nails, which become grey. Mercury is always demonstrable in the urine during the second period of intoxication; in the first period albuminuria is rare (according to some authors it is said to be frequent!) even during a long period of elimination of mercury.

HYGIENE

General hygienic measures for the workrooms and workers, such as: cloakrooms, protective clothing, caps, washing accommodation, baths, placards, etc., are provided for in Belgium, France, Germany, the Netherlands, and Missouri; substitution of hand labour by machines with localised ventilation is required.

Gloves should be at the disposal of persons engaged in brushing and cutting.

The use of the brush in carotting does not require the wrist and forearm to be specially protected. Gloves, so often recommended, constitute, on the contrary, a regular compress of the acid nitrate. They are expensive, wear out quickly, obstruct perspiration and favour the onset of dermatitis. Anointing the skin with black soap is also a cause of dermatitis. It would be better to use a neutral fat or a non acid vaseline.

The wearing of goggles to protect the eyes against acid splashes, and to prevent the workers rubbing their eyes with their wet hands (chronic conjunctivitis is very frequent) is to be recommended; also the use of a mouth wash containing a little iodine. (See also article "Mercury").

Prohibition of preliminary work on skins to be carotted in the home is required in Belgium. Experience is against allowing women to work on machine carotting.

Initial medical examination and periodic medical examination at quarterly intervals is required in Belgium and France; once a year in Austria (where the frequency of the visits might be increased); monthly in Missouri.

Suspension of workers seriously affected by mercurialism and of alcoholic subjects from all work exposing them to poisoning should be insisted on as well as the provision of a Health Register to be shown to the Inspector on demand (Belgium, France, and Germany). The Dutch law provides that the Inspector may demand a certificate of fitness in the case of women and young persons under eighteen years of age.

For compulsory notification, see article "Mercury".

Carotting without mercury. — In spite of the improvements made in the industry, the use of acid nitrate of mercury must always be a menace to the health of the workers. The search for a substitute dates back very far and it would have been of advantage to the industry if a substitute could have been found, as the nitrate is very expensive. While it is customary to state that mercury carotting cannot be replaced, the statement is true only for a part of the industry. Proof of the possibility of replacing mercury exists, and the only reason advanced for not making its discontinuance general is that the appearance of the fur carotied without mercury differs from that to which the trade is accustomed. An international agreement might possibly ensure the abolition of mercury from hatters furriers' processes and hat making.

generally speaking, it can be said that all acid salts might serve for carotting fur, but not all equally well and, above all, not at the same cost. And even in the case of the acid nitrate of mercury, the manner in which it acts is very obscure.

For a long time it was thought that the action of the acid nitrate favoured by the heat of the stove caused the hair
cells to split and spread out in such a way as to facilitate felting; but there does not seem any sound basis for this view. Some writers maintain that the free acid partially destroys and profoundly modifies the cuticle of the hairs, the acid corroding the hair so as to give it the property of felting. The metal is thought not to play a specially direct rôle, but to exercise some sort of catalytic action, and the action once started is thought to go on of itself. The real rôle of the mercury is said to be to act as a preservative agent on the hair. Microscopical examination of carotted and "soft" hair often does not show any difference, except, perhaps, greater surface roughness of the carotted hair (Gilbert).

Attempts to seek a substitute in other metallic salts or even other substances have proceeded on the assumption that the felting action is due to the nitrous or hyponitric acid acting in a latent condition.

The substitutes are not numerous—chlorides, sulphates, and nitrates. The organic acid salts do not give good results; sulphuric acid, proposed in 1818 by Guichardière, reduces the skin to a parchment-like condition, thus interfering with glue making (from the "vermicelli" of cutting); chlorides give moderate results, but are dearer than nitrates; the nitrates, therefore, answer the purpose.

Though the first process of Mallard and Desfosses (use of an alkaline solution), which obtained a medal at the Competition of the Society for the Advancement of National Industry (Paris, 1815), was never applied in such a way as to enable judgment to be passed on its quality, the processes which have been followed since 1869 have yielded practical results.

Dr. Hillairet (1889) proposed molasses and dilute nitric acid; Bargeron (1872) recommended this process to the Academy of Sciences, and Delpch submitted it again to the Academy on 5 November 1884. The process consists in brushing the skin with the following solution:

For white carotting: molasses = 8.5 kg.
water = 14.0 kg.

For yellow carotting: molasses = 10.0 kg.
water = 15.0 kg.

and subsequently with the following acid solution:

For white carotting: nitric acid at 38° B. = 12.0 kg.
water = 10.0 kg.

For yellow carotting: nitric acid at 38° B. = 16.5 kg.
water = 14.0 kg.

The skin is kept in the stove for 12 to 16 hours at a low temperature, so as to allow the process to proceed slowly, and is then well washed with water. Hillairet's process (patented by J. H. Johnson in Great Britain in 1867) was used in the carotting laboratory of the Hessler before 1870, but after the war of 1870 was never taken up again. Schoull, in 1882, proposed the use of calcium sulphide dissolved in water and slightly acidulated with hydrochloric acid.

In 1884 Grossot proposed a mixture of creosote, oil, alcohol, water and nitric acid; and in 1887 Dargelos proposed aqua regia.

In 1886, the Americans, Tweedy, Bevoort and Roberts, obtained a German patent for the following process: 1 kg. of permanganate of potash dissolved in 40 litres of water at 27° C. To 1 1/2 litres of the solution is added 10 grm. of sulphuric or hydrochloric acid. The skins treated with this solution are dried in a stove at 65° C. and treated then with oxygenated water, diluted with water to 3/4 per cent. of its weight. The skins and the hairs are exposed to the action of the oxidising vapour, e.g. nitric or nitrous acid and water vapour. There are no data as to the practical value of this method.

The Fabre process (1890) has as its basis a decoction of curcuma (or other vegetable astringent) and a solution of alum, sodium, chloride, and a little sulphuric acid.

Courtonne (11 April 1891, Patent 212706) speaks of good results obtained with metallic chlorides (zinc, antimony, and tin) with or without some acid, preferably hydrochloric acid (e.g. salt of tin 1 1/2 kg.; ordinary hydrochloric acid 1 kg.; water 1 kg.). The process reduces the cost price by more than 40 per cent. Good results are confirmed by Espanet (1907), General Secretary of the Federal Union of the Textile Workers (4th Category, Paris).

Burg (1892), however, states that nitric acid alone is not sufficient for carotting, and is of opinion that a good pale carotting without mercury cannot be secured, except with sulphates of potassium and zinc.

The solutions prepared by Burg were as follows:

(1) 1 litre of water, 3 1/2 grm. of tannin, 20 grm. of sulphate of copper, and 10 grm. of sulphate of zinc. To this is added about 110 grm. of nitric acid in order to have a density of 8° B.

(2) 1 litre of water, 3.5 grm. of tannin, 10 grm. of sulphate of sodium, 20 grm. of sulphate of zinc, and 2 grm. of chloride of calcium. To this is added
about 75 grm. of nitric acid to secure a density of 5.5° B.

In 1892 Jungfeisch described his carotting solution to the Academy of Medicine, Paris, and Lussigny secured, on 17 October of the same year, Patent 224980 for a process based on a solution of caustic potash of a strength of 6 to 10° B. This process was used by the firm of Jourde and Sons, Paris, and, especially before the war, in the hatting district of Podolsk, in Russia, after the favourable advice of the Council of Hygiene of the Zemstwo of Moscow.

Experts assert that caustic alkalies, as they act strongly as solvents of animal textile matters, have been abandoned, and that if the process of Lussigny is still employed it must have undergone modification.

Acids alone can render hair capable of felting, but never to the same degree as when metallic acid nitrates are used; further, the treated skins do not last.

Among the processes with a basis of acid nitrates is one of nitrate of zinc, and especially one of acid nitrate and tin proposed by Ronjat (Paris). In the formula ordinarily used, mercury is replaced by tin as follows: yellow carotting, 2,650 kg. of tin; pale carotting, 4,720 kg. of tin, which replace the chemical equivalent of mercury.

The acid nitrate is prepared in the same proportions as with mercury, but without evolution of nitrous fumes. The technique is exactly the same as for carotting with mercury.

Hair carotted with nitrate of tin is said to have the same characteristic properties as that treated with mercury. The only difference is said to be that hairs treated with tin preserve their natural colour, while those treated with mercury take on a rose colour in storage, a colour which has not, however, any influence on the value of the carotting. Hair carotted with tin is said to keep as well in storage. In Great Britain L. F. Paris patented in 1914 (No. 5409) a process based on nitrite, hypochlorite of soda, zinc chloride, nitric and hydrochloric acid. Braun in U.S.A. also brought out in 1917 (Patent 1215246) a hot carotting process, using an aqueous solution of carbonate of soda.

All requests for information as to the methods of Kurz, of Göttingen, which is said to be used in the Berfeld factory of Blihenrod (North Hesse), failed to elicit a reply. The skin is said to be carotted by use of a cold mixture consisting of a solution of sumac and nitric acid. The results appear to be very satisfactory.

**LEGISLATION**

(See also article “Felt Hat Industry.”)

Women are prohibited from work in carotting, and processes subsequent to it, in France, Japan, and Switzerland. (See article “Mercury.”)

Young persons of less than 15 years of age are excluded from work with compounds of mercury, and where dusts, even non-toxic dusts, are given off (Japan); young persons of less than 16 years in sorting the hair, and where dusts, even non-toxic dusts, are given off (United States); in Belgium, Spain, Italy, Japan, and where use is made of toxic acids (Idem, and also: Arkansas, Colorado, Florida, Illinois, Minnesota, Nevada, North Dakota, Oklahoma, Pennsylvania, Utah), before and after carotting (Belgium); young persons of less than 17 years (Netherlands); young persons of less than 18 years where mercury vapour is given off (France).

Young persons under 15 years are excluded in Italy, Rumania (carotting and fur cutting), and Japan (where there is evolution of much dust in the treatment of animal hair); of less than 16 years, in Belgium, Greece, Spain (which exclude them from cleaning the skins, fur pulling, cutting, etc., of the hair of rabbits and hares).

Female young persons of less than 17 years of age are excluded in Rumania; of less than 18 in Greece, and of less than 21 in Belgium, Spain, Italy, Japan (with the same conditions in the case of male young persons):

Special legislation for hatters furriers’ processes and carotting:

**Germnay.** Ministerial Decrees of 4 January 1901 (IIIa 9265) and 11 January 1902 for Prussia; 9 July 1901 and 20 January 1902 for Saxony; 11 October 1907 for the Grand Duchy of Hesse (District of Düsseldorf); 21 February 1892 for Düsseldorf.

*Belgium.* Royal Decree of 10 August 1912.

*France.* Decree of 1 October 1913. Compulsory notification of cases of mercury poisoning occurring amongst carotters of skins.

*Holland.* (See Section C of the Regulations under the Safety Act of 21 August 1916, and of the Factory Act of 1 November 1919.)


For individual measures, see the account already given for each phase of the industry. For compensation in cases of mercury poisoning, see article “Mercury.”

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BIOT. *Contribution à l'étude du mercuralisme des ouvriers des couperies de
Hairdressers


Hairdressers are exposed to conditions inimical to health not unlike those affecting washerwomen and domestic servants: frequent contact with soap and water for example, or with alcoholic solutions of potash soap in rubbing, so as to make a good lather for shaving or shampooing. The use of these solutions, as well as stimulating lotions or dyes applied to the scalp, frequently gives rise to irritations of the skin because they sometimes contain cantharides, phenylenediamines, aniline, etc. Cases of lead poisoning have also been reported from the use of cosmetics or dyes with a lead basis. Such cases are certainly more frequent in the Far East.

The dermatitis thus occasioned are generally of popular eczematous nature, localised on the hands and fingers, but they may extend to the arms. Severe eczematous conditions have been found in hairdressers, especially among those using dyes. Cuts in shaving may be the vehicles of illnesses transmitted by customers. The use of greasy substances and perfumes may set up changes in the nails. Powder and especially fragments of hair floating in the atmosphere of the shop often cause irritation of the eyes.

Undoubtedly the health conditions of hairdressers are unfavourably influenced by the fact that many persons of poor constitution and physically unsuitable seek employment in this profession. This accounts for the fact that the tuberculous rate is higher than the average rate met with in industry generally. Hairdressers suffer from catarrhal affections of the upper air passages, digestive troubles, flat feet, and dermatitis.

According to the Vienna Sickness Insurance Society, incidence of venereal diseases among hairdressers, during the period 1902-1905, reached a rate of 63.9 per 1,000 members as compared with one of nearly 32 for all members.

According to the statistics of the Leipzig Sickness Fund, incapacity for work due to sickness amongst hairdressers amounted to 395 days per hundred members per annum, and the mortality rate to 0.32 per cent.

Data of a Berlin sickness insurance society gave the following proportion of cases for phytodermatoses as compared with other skin diseases, excluding venereal diseases: 1915, 2.2 per cent.; 1916, 5 per cent.; first half of 1917, 9 per cent.; second half of 1917, 23 per cent.; January 1918, 28.8 per cent.

Knowles found 15 cases of eczema localised on the hands of barbers. Fordyce saw some very severe cases of eczematous dermatitis in hairdressers who used dyes containing aniline, besides a case of dermatitis of the hands from the use of a "tonic" solution for the hair. Its composition was :ot known. (See also the article "Hair").

Hairdressers are also exposed to risks of contagion from their customers, and the public is exposed to the risk of contracting all sorts of infections which may be spread in hairdressing establishments.

During the war and afterwards, the question of the hygiene of the industry became very prominent because of the increase in the spread of contagious diseases in barbers' shops in consequence of insanitary condition. Epidemics were described from microspores, trichophyton, taurus, staphylococci, and even cases of syphilis from inoculation. Finally, several cases of anthrax were conveyed by shaving brushes.

In the course of an enquiry undertaken at Zurich, examination was made of the shaving-brushes, hairbrushes, combs, sponges, scissors, clippers, straws, towels, and even of the air of the room. It should be said that the establishments were submitted to this enquiry of their own free will and were among the best kept from a hygienic standpoint.

The enquiry showed that even the best-kept barbers' shops contained material that was seriously infected. Much effort is wanted to secure proper cleanliness of the rooms, the personnel, and the instruments. The shaving-brushes were most infected and are consequently the greatest source of danger.

**HYGIENE**

Cleanliness of hairdressing shops, cleanliness and disinfection of all...
implements, including the linen wraps and serviettes, as well as cleanliness of the hairdressers concerned, is required. The latter should be careful to avoid contagion from their customers. Obligatory notification of certain diseases is desirable. According to the Zurich enquiry, shaving brushes are often left quite a long time standing in soapy water after they have been used, where any bacteria present will multiply rapidly. It is very difficult and sometimes even impossible to yet rid of these, especially if the bacteria are situated inside the shaving brushes. Chemical disinfection would take hours; disinfection by steam or boiling water, which is effective, has the defect of loosening the bristles. Disinfection by dry heat is expensive and less efficient. It would, therefore, be useful to replace these brushes by cotton-wool pads enclosed in gauze, a fresh one to be used for each customer. In no case should soap be applied by the hand. Numerous germs have also been found in the sponges. The sponges are damaged by hot alkalis; on the other hand, chemical disinfection is not easily practicable. The best way out of the difficulty would be not to use them. Powder puffs or brushes similarly would be best replaced by cotton-wool pads, a fresh one to be used each time. Contrary to what has been said of the above articles, razors do not offer a suitable soil for germs; nevertheless they are often found badly infected from the fact that they have been in contact with infected skin. It is not sufficient, as is often done, to dip them in alcohol, lysoform, or to pass them through a flame. To dip them however for two seconds in boiling water gives the best results. This precaution ought to be taken before and after using the razor. Strops are also often infectious. Their disinfection with alcoholic solutions is quite useless, while chemical disinfection may damage them. Sterilisation of the razor blades in boiling water before and after use should be sufficient to prevent infection from the strops. The serviettes used ought not merely to be rinsed and dried as is often the case. It would be better if they were washed and boiled every time, but that is hardly practicable and would wear them out quickly. Careful hot ironing should suffice to destroy bacteria of all sorts. Application of alum to the shaven skin is of no use in destroying bacteria, as is often imagined, but tends rather to shelter them in its minute cracks. It can thus be a source of infection, and its use should be severely restricted. Brushes and combs are less important than the shaving materials. Examination has, however, often disclosed a high percentage of bacteria in them. As in the case of razors, complete disinfection after each usage, ideal though it is from a hygienic point of view, is hardly practicable and could only be demanded in the case of epidemic diseases of the hair. A sufficiently frequent cleansing and permitting of the destruction of crypto-gamic germs is all that can be asked for. Lysoform, which is often used, is inadequate. Soap and soda solutions to be effective ought to be of a temperature of 60°C., which would destroy the germs. Immersion for some minutes in an ammoniacal solution (10 per cent.) at the temperature of the body (30-40°C.) is an easy practical method of destroying the germs. Use of brushes for applying oils or ointments to the beard ought to be prohibited.

Scissors and clippers, particularly the latter because of their sharpness and their use on the neck, are often the means of transmitting disease. These metal instruments can be disinfected by simple immersion in boiling water after use. Overalls and towels used during haircutting often act as agents for transmission of infections and should be preferably replaced by paper serviettes which should be destroyed after use. Hairdressers' overalls should be kept in a proper state of cleanliness if not changed for each customer. Pastes and pomades should be supplied in tubes rather than in open pots, and should be applied with cotton wool, which should be immediately destroyed.

**LEGALIZATION**

The data on legislation concerning hairdressing establishments cannot be given, as it generally devolves on the local authorities. As a matter of fact, local authorities have made by-laws as to the precautions to be taken in such places against the transmission of skin diseases.

Special measures, too, have been passed on the manufacture, sale, and importation of shaving brushes (compulsory disinfection).

**BIBLIOGRAPHY**

Heating

The output of a labourer, under certain conditions of latitude or season, or even of work may be profoundly affected by the surrounding temperature being too low or too high.

There is given in detail in the article "Temperature" the influence of low or high temperature on the body at rest and at work and the damage which may result therefrom.

This article deals briefly with installations used for heating workplaces.

The temperature of a place is well known to depend on several factors: external temperature; radiation from lighting apparatus, pipes, machines, and any furnaces, vats, stoves, and drying rooms which may be in the place; the temperature required for carrying on the industry; friction from machines and its transformation into heat; radiation from the human body, the temperature of which is almost always higher than that of its surroundings.

On the other hand, factors exist which favour the loss of heat, part of which is removed by various goods which leave the works. The greatest loss is, however, due to exchange with the external atmosphere surrounding the walls, ceiling and, especially, the windows, as well as to ventilation and radiation.

Modern factories have almost all their walls composed of window glass, so that the loss of heat is enormous. The question of heating in the cold season becomes in consequence one of great importance.

In other factories the loss by radiation and conduction varies according to the seasons, and in the cold season according to other factors, such as the position of the factory, whether in a valley or on a plain, or sheltered from winds; whether the building has several floors or consists of sheds; the thickness of the walls; the kind of walls, whether more or less conductors of heat.

Thus, for example, if in still air the loss of heat in a factory consisting of sheds should happen to be 0.66 per cubic metre per hour per degree that the internal temperature exceeds the external, then it may reach 0.75 to 0.80 under the same conditions if the air is agitated.

The variation in loss is greater or less according to the difference in temperature between the two. When there is equilibrium, the human body is in the best condition possible, even without either heating or cooling. But as soon as this equilibrium is disturbed, as in the cold season, the air of the factory must be heated, in order to avoid reducing the output of the workers and causing more or less serious injury to their health. The surrounding temperature must then be such as to prevent a fall in the temperature of the body, manifested by a sensation of cold and numbness.

There is clearly an optimum temperature for the body; but this optimum varies according to individuals and according to physical occupational activity.

Fat persons are notoriously more resistant to cold than thin ones; so are persons who are warmly clad. A low temperature is comparatively better borne by workers who are employed on work requiring effort, such as manual labourers and rivet-drivers, than by those who are employed on sedentary work, like tailors and clerks.

As a rule legal regulations for the heating of workplaces are far too vague (see later). It would be an excellent thing if the limits of temperature most suitable for each type of occupation were to be defined.

It is admitted, in a manner which is little arbitrary, that 15° C. represents an optimum for persons occupied at work which does not require muscular effort, and that 10° C. is sufficient in cases of muscular work.

But these averages no longer apply if special conditions intervene, for instance humidity, and for this reason it is difficult to separate the question of air temperature from that of humidity (see article "Air — Hot and Humid").

In France, Lebrasseur, at the Industrial Hygiene Congress at Rheims in 1909, and Maniguet (quoted by Razous) give the following figures (in degrees Centigrade):

<table>
<thead>
<tr>
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<th>Minimum</th>
<th>Maximum</th>
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<tbody>
<tr>
<td>Sedentary workers without violent muscular efforts (Lebrasseur)</td>
<td>15°</td>
<td>20°</td>
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<tr>
<td>Sedentary workers with muscular efforts (idem)</td>
<td>13°</td>
<td>18°</td>
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<tr>
<td>Heavy work with muscular efforts (idem)</td>
<td>10°</td>
<td>15°</td>
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<tr>
<td>Workshops with men moving about, according to the occupation (Maniguet) (winter)</td>
<td>14°</td>
<td>19°</td>
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<td>Workshops for seated women (idem)</td>
<td>18°</td>
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<td>Shops (idem)</td>
<td>16°</td>
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<td>Offices (idem)</td>
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In Germany, Albrecht has expressed the view that it is not possible to fix absolutely optima for atmospheric temperatures; other experts have proposed that 30° to 15° C. and 20° C. in winter should be the standard for sedentary workers.

Sackermann is of opinion that, where the law has not decided otherwise, the optima for atmospheric temperatures should be as follows:

- Places of work in general 20° C.
- Light manual work 18°
- Heavy work 15°
- Foundries 10°
- Carpenters' shops 30°
- Lacquering shops 25° to 30°.
- Lecture theatres, class-rooms, schools and meeting halls 18°
- Offices 20°
- Staircases 10°

In Great Britain, Haldane and Osborne consider that atmospheric temperature should not be below 15.5° C., especially if light sedentary work is in progress. Legge in 1903, in his annual report, was quite right in asking: "What is understood by an 'adequate' temperature from the point of view of factory law?" A temperature which suits one person and does not cause that person any sensation of cold and does not interfere with his productive capacity may not be the same for his fellow-workman. It has been seen what are the individual factors which come into play and what are the conditions of work which have to be taken into account; this is why it is necessary to endeavour to fix the atmospheric temperature at a point which causes the least sensation of discomfort, such as might be resented by the majority present.

The object of heating is to establish an equilibrium between the balance of calories gained, on the one hand, and that of the calories lost by the walls, by goods removed, or by ventilation, on the other hand, in such a way that the resulting temperature of the place may be constant at the selected optimum.

The heating apparatus which the manufacturer chooses to attain this object should comply with a certain number of conditions: (a) it must not foul the air of the factories by fumes, or deleterious gases; (b) it must not dry the air too much, nor saturate it with moisture; and (c) it must not cause cold draughts.

Generally speaking, a heating apparatus includes a furnace, where combustion takes place and heat is given off; a medium which accepts and conveys heat, whose function it is to carry the heat to the rooms to be warmed; and a chimney for the removal of the gases of combustion, e.g. carbon monoxide, carbonic acid, sulphur fumes, and dust.

The fuel used for heating varies considerably according to local conditions or the situation of the works. Wood is very rarely used to-day; but lignite, peat, coke, coal, naphtha, and oil are all used. It is not necessary to dwell in more detail here on the advantages of each of these types of fuel.

The medium which accepts and conveys heat may be either the air of the room to be warmed which is heated from a chimney or by stoves, or a fluid capable of carrying the heat to a distance with as little loss as possible, for which purpose air, water, and steam at high or low pressure may be used.

Heating apparatus may be divided into two main categories: (a) apparatus for local heating, and (b) apparatus for central heating.

(a) Local Heating

Hereunder may be grouped open fireplaces, used little or not at all in industry, braziers, ordinary stoves, or slow combustion stoves; gas, petrol, and electric apparatus. These different types of apparatus may be examined briefly.

Ordinary fireplaces certainly have the advantage of helping local ventilation, but on the other hand have several disadvantages, among which is that of being far from economical. So-called ventilator-fireplaces utilise not only radiant heat from the grate, but also that from the sides of the hearth. External air is introduced by a flue into a chamber which surround the hearth and chimney flue; it gains access to the place which is to be heated by special openings. Another type consists of a gas fire in which flames from Bunsen burners are directed upwards to the top of the fire-place, formed by a concave metallic surface, or they heat to incandescence asbestos tufts, or blocks of asbestos or special refractory material.

Braziers should be strictly forbidden, even in workplaces by no means hermetically closed. Sometimes the hoppers of braziers are surmounted by a ventilating cowl furnished with a shaft for extracting the fumes. But if this shaft does not, by passing through the roof, convey outside the gases from the combustion, and only confines itself to diverting them into the workshop to be heated, it is useless.

In stoves the combustion takes place in a closed grate and the gases escape
and are passed into a chimney through a pipe which is carried across the place to be warmed.

Quick combustion stoves have metal or tiled sides and burn all kinds of fuel. Whereas this type of apparatus has the advantage of putting to use 80 to 90 per cent. of the heat given off, of being inexpensive and easy to install, and of being economical because it burns all kinds of fuel, it has on the other hand several disadvantages: it only heats in an unequal manner and in a very restricted radius; it gives off from the red hot metal sides (if it is not furnished internally with a firebrick lining or if it is not double) poisonous gases from combustion; it dries the air itself to evaporate a certain quantity of water and so to increase the humidity of the surrounding air; and to surround the stove with a metal sleeve, in the interior of which an ascending current of air will be produced to escape and diffuse itself throughout the room after having been heated. In this way direct radiation is avoided; but it is necessary to provide in the sleeve a narrow opening so as to make sure that the interior does not become red hot; to regulate combustion by a control which acts only on the air inlets, and not by a damper in the chimney; to place on the top of the chimney flue a contrivance (revolving chimney can, for example) which will prevent any current of air

![Central heating by oil at the International Labour Office.](image)

It is a source of dust when charging with fuel and removing the cinders.

Barber, who has studied the problem of heating by stoves, considers that this type of heating, in spite of all its bad points, cannot be absolutely prohibited; it must be tolerated in a good number of small workshops and it can be improved so as to reduce to a minimum the disadvantages it presents.

He considers that it is possible: to place ventilating sleeves, which will assist in renewing the air, at the points where the chimney pipe passes through the roof; to use the heat of the stove flowing into the flue from above downwards. These precautions should prevent any back current into the room of the gases of combustion and obviate a reverse current which sometimes occurs in this type of heating.

The slow combustion type of stove presents the same disadvantages, only multiplied, of the preceding type. Very careful supervision is necessary to prevent the back currents of carbon monoxide. For this reason they are being used less and less.

For intermittent heating, gas or oil stoves are sometimes used. While these stoves require little care, they
are on the other hand sources of carbon monoxide, even when they are supplied with so-called exhaust pipes. The position created by oil stoves is more serious, for they generally take the form of large lamps or of hot plates without exhaust flues.

From the hygienic point of view, the best heating apparatus is the electric. It is very convenient, takes up little room, can be regulated easily and is particularly useful for heating particular parts of rooms—a worktable in an office, for example. This type of heating does not give any ashes, dust, fumes, or gases of combustion. The only objection to its more general use is that the cost price is still too high on account of the electric current required.

This type of heating, which is comparatively new, is, however, steadily increasing. Where direct heating is of secondary importance, central heating by circulating hot water, and using the electric current during the slack hours must now be regarded as an accepted fact. A third, the plenum system with propulsion of hot air, consists in blowing air by means of a ventilating fan across special radiators which are kept at a temperature of 400°-500° C.

(b) Central Heating

In this system the building is heated by means of a central furnace situated in the basement; but in some cases it may be on the same floor as the workshop to be heated. The heat produced passes into a medium which accepts it and carries it by a system of pipes to the places to be heated. The installations used may be classed according to the medium by which the heat is conveyed, but more than one medium (as in aero-condensers) may sometimes be used simultaneously: heating by air, steam, water and aero-condensers.

Heating by hot air is the oldest system. The furnaces used by the Romans were placed in the basement or on the outside of the rooms; flames and smoke circulated in passages covered over by

Fig. 169. — Heating installation by "Radiant" (made by Neu). (Reproduced from La Technique Moderne, 1927, No. 19, Paris.)
flagstones on the ground level, and ascended in flues in the thickness of the walls, giving off their heat to the air through the flagstones and the walls. This type has, of course, been improved and has developed into three types: central heating of air which is conveyed in conduits for distribution; local heating of air which is conveyed in closed pipes; local heating of air without special conduits.

The first system is the most used, especially for large rooms where great quantities of air escape through outlets and are replaced by cold air which must be warmed at once. The air enters the workplace by means of warm air inlets at a speed of about 4 metres a second. The heated air is of course thoroughly separated from the fumes and gases of combustion. With other systems the air is heated by passing it over plates heated by the circulation of water or steam.

The principal methods of heating with hot air are: heating with ventilation, where heated fresh air is passed into a workplace, and, after it has given off its heat directly, is passed out cooled to the outside; heating by circulation, where the cooled air returns to the heating apparatus to be heated afresh; heating by a mixed system.

Heating by air is not much used for technical and hygienic reasons. The technique has certain difficulties of construction for the distribution of the heat, and this requires an increased number of heating centres when the building is a large one. The devices proposed to avoid this disadvantage are not practical. From the hygienic point of view, there is risk of sending vitiated air into the workshops if the installation is not perfectly air-tight; of raising the temperature of the air too high when, during periods of great cold, the stokers make large fires; of imparting to the atmosphere a disagreeable smell due to carbonising dust, and of drying it. These disadvantages may always be overcome if a humidifier is installed and if the warm air is filtered as far as possible. It would be better for the air to be warmed by surfaces heated by steam or hot water.

An improvement is to heat by water carried in pipes and in radiators which warm the air of the rooms by contact. The installation can be worked by using the low or high pressure system or by rapid circulation. The favourite system is that of low pressure, although the installation is costly: its advantages are numerous both from the technical point of view and from the hygienic point of view; there is no danger of fire; every facility exists for increasing the heating surface; the degree of heat can be controlled according to requirements, even by means of automatic apparatus; there is no overheating of the air, or burning of dust; and no contamination of the air of the rooms by the products of combustion.

Heating with a high pressure system is open to the same disadvantages as with high pressure steam. This is why it has now been abandoned.

Central heating by steam may be either at high pressure, which, how-
ing method is that it can heat at much greater distances, i.e., half a kilometre.

Heating by waste steam utilises steam escaping direct from an engine or from a recuperator, and uses it like ordinary steam of the same tension.

Heating at a pressure less than one atmosphere has been adopted fairly widely in the United States under the name of the "vacuum" system. It has several advantages: it utilises effectively the heat produced; it maintains a more rapid circulation, which makes it possible to use pipes of small diameter; it is possible to regulate the temperature easily. From the hygienic point of view, there are no disadvantages, but technicians raise objections to it.

In any heating installation a much better transmission of heat is obtained by a foundation without mechanical ventilation, because, when the air is in motion, the increase of the coefficient of transmission from a steam radiator is in proportion to the square root of the velocity of the air; which gives an average increase of 25 per cent. in the heat of contact per metre of velocity. It is not possible to enter into technical details which come within the province of the engineering specialist. It will be sufficient to mention some points of hygienic interest.

The heating chamber must be well ventilated, and in front of the furnaces a clear space of about 2 metres must be provided; all must be arranged so as to allow easy exit for the stoker in two directions in case of a serious escape from a generator which might block one of the ways of retreat.

A few words suffice for the system by which the heat is obtained by means of apparatus for varying the temperature. Heat generating units act as aerotherms, fed by steam at low, average or high pressure, or as aercondensers using waste steam. The form varies according to the makers and requirements, e.g., Neu's radiant, and the steam air-heater made by Nessi Brothers. Change of temperature devices are suitable for drying various products and for apparatus used for removing mist. Another type is that for warming up air by placing it close to a furnace without having to resort to the production of steam. The air is blown into the warming apparatus at the same time as ventilation air.

Modern technique now makes it possible to utilise calories supplied by a furnace owing to the use of tempered steel in the construction of the apparatus.

It has also been suggested to make warm air circulate in the walls of the workshops by means of double walls.

In summer it would be equally advantageous to pass cold air through in order to protect the workshop from outside heat.

But as a general rule the manufacturer has recourse to heating installations combined with a system of ventilation and humidification, e.g., in the textile industry, by combining the mechanical apparatus of the different systems.

In other cases the question is complicated by particular conditions: an installation of dust exhausts may cause an inflow of external air and annul thus in part the effects of the heating apparatus; or it may be necessary to adopt a special type of heating, as in chemical and explosive industries and everywhere where there is a danger of fire.

Heating surfaces are composed of radiators, flanged pipes (rarely smooth pipes) placed in the workplaces to be heated. The placing of radiators deserves the attention of those interested. If the heating surfaces are located in out-of-the-way places so that the external air heated there passes by before reaching the inlets for heat in the room to be heated, the value of the installation is much diminished. It is for this reason that it is considered preferable to place radiators in the places to be heated below the windows and in front of the special inlets for fresh air. In this way the air becomes warm before passing into the room and causes a ventilation which improves that of the room. An opening placed near the ceiling completes the installation and enables vitiated air to escape outside.

Flanged pipes are sometimes arranged along the length of the walls — cold, external ones by preference; in other cases they are suspended in the middle of the hall at a height exactly determined. Their position is of great importance when steam is given off in the workplace or when the atmosphere has a high degree of humidity.

In offices radiators are often hidden in cases which are more or less handsome. This method has the disadvantage of making the transmission of heat difficult, and of accumulating dust on the flanges of the radiators and of necessitating in consequence frequent cleaning.

It is no concern of the hygienist to calculate the calories required for a given heating apparatus to maintain the indispensable minimum of heat in a room or a building. That is the province of the special engineer.

The regulation of the temperature is checked in the rooms by means of thermometers. Apparatus for regulating
the temperature at a distance is now coming more and more into use, so that the stoker may have it in the same place where the other apparatus for the control of heating is all placed. In this way the temperature in the various workplaces heated by the system can be quickly ascertained, and results due to inefficient working of the apparatus can be quickly corrected or the dangers of overheating prevented. Apparatus for the automatic regulation of temperature should also be referred to; thermostats may be interpolated in hot water or steam systems or electric heating and an automatic flow of heat may be so secured that it is possible to keep the desired temperature constant.

In some conditions it is also advisable to regulate the salubrity of the air. Thus, for instance, with heating effected by open fires, the index of toxicity varies in a quite unexpected manner according to the fuel used (Kohn-Abrest). Gas apparatus does not give a high index, except some incandescent burners (Kling and Florentin). When heating is carried out by gas stoves or braziers it is necessary to ensure good ventilation in the room, and not to use burners (Kuhn-Abrest). Thus, for instance, with heating effects by open fires, the index of toxicity varies in a quite unexpected manner according to the fuel used (Kohn-Abrest). Gas apparatus does not give a high index, except some incandescent burners (Kling and Florentin).

**LEGISLATION**

Beyond the special measures laid down by law in particular cases the general measures dealing with heating of workplaces are as follows:

**Austria** (1905). — Heating of workplaces must be effected by means of apparatus which avoids any danger of fire and any injury due to radiant heat. Apparatus of the stove type must be protected by a grating or screen. In workshops or places where there is danger of fire or explosion, a type of heating apparatus must be installed which will overcome the risks in question.

**Belgium** (1905). — During the cold season the workplaces must be properly heated. The same arrangement has been made by Luxemburg (1904).

**Denmark** (1910). — The inspectorate can insist on the heating of enclosed workplaces when it can be done without undue expense.

**France** (1913). — Enclosed workplaces shall be properly heated in winter.

**Great Britain** (1901). — In every factory and every workshop necessary measures which do not change the composition of the air shall be taken to ensure and maintain a reasonable temperature. The law requires that thermometers be placed in certain workplaces.

**Italy** (1927). — The temperature of enclosed workplaces must be maintained within such limits as to allow the good performance of work and to avoid all risk of injury to the health of the workers. The temperature of a workplace shall be estimated by taking into account the influence exercised by the humidity and movement of the atmosphere. Heating apparatus of the stove type used in enclosed workplaces shall be supplied with exit flues without dampers or regulators in order to prevent the vitiation of the air. The law provides for the protection of workers against radiant heat from heating apparatus.

**Netherlands** (1920). — The employment of young persons or adult women is prohibited if the workplace where sedentary work is carried on is, during the cold season, less than 10° C., or the temperature which the inspector considers necessary. In the case of offices, the minimum temperature is 15° C. or that considered necessary by the inspector. The regulations also require a thermometer in good working order to be kept in the workplace.

**Norway** (1909). — Workplaces must be heated in an adequate manner so far as the conditions of the industry and the nature of the work allow.

**Sweden** (1912). — Work must be carried on in places warmed to an adequate temperature depending on the nature of the work and that of the place in question.

**Switzerland** (1914-1919). — Workplaces must be heated in the cold season as far as the nature of the work carried on allows. Stoves without chimneys for the removal of the gases of combustion must not be used. Workers must be protected against radiant heat, as well as against currents of hot air which might injure them.

**Yugoslavia** (1921). — The temperature of workplaces must be reasonable (14°-19° C.). The use of braziers is forbidden, as well as that of furnaces which open directly into closed-in places of work. Heating apparatus must be guaranteed against danger of fire and of giving off unhealthy gases. Iron furnaces shall be furnished with a fender or screen.

There have also been enacted legislative measures providing for the warming of workers employed in the open air, such as men in shipbuilding yards, farm labourers, stone workers, and quarry men; likewise for heating places used for sleeping accommodation. Special measures have also been laid down for women and young persons employed in selling outside shops (see articles "Children" and "Women").

**BIBLIOGRAPHY**


Hemp Manufacture


In this article in speaking of hemp, reference is made exclusively to the product of the Cannabis sativa plant, excluding all other textiles which sometimes pass under the name of hemp, but are not derived from the Cannabis family, as, for instance, the Yucatan or Sisal hemp, derived from the American aloe, aquatic hemp (Hemp-agrimony), Bengal hemp (Crotalaria), Japanese hemp (Spiroea), African (Sansevierie), Indian (Aloes), Manila, or Henequen (Banana tree), New Zealand (Phorrium), etc.

The spinning operations, however, of these various textiles are very similar to those of linen or ordinary hemp.

Several varieties of hemp are cultivated bearing the names of the species, for instance, Cannabis indica or chthensis, but as a matter of fact it would appear that, allowing for slight modification due to climate and soil, there is really only the one species. For instance, the head of Cannabis indica is richer in cannabinine than most of the varieties (although they all contain abundant cannabinine), more especially since it has grown in a warmer and drier climate.

While flax is cultivated only for the sake of its fibres and seeds from which oil is derived, hemp has spread all over the East for the purpose of producing "hashish," an intoxicating drug which owes its properties to the resin, cannabine, to which reference has just been made.

According to the data supplied by the Enquiry on Production (I.O., Vol. II, Vol. I. 1920), the production of hemp tow shows the following figures (in metric hundredweights) for the year 1921 (1921-1923).

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The cultivation of hemp, which is a dioecious plant, is a little more complicated than that of hermaphrodite flax. If the seeds are not wanted for gathering, it can be sown very close together and pulled up in masses as soon as the so-called female stalks — which in reality are the male — are not too ripe, and the so-called male stalks are just about ripe enough. Thus, a mixed tow is obtained which has some advantages in suppleness. Generally hemp is sown some distance apart in a line in order that the so-called female stalks can be pulled up as soon as fertilisation has taken place, while the "male", which contains the seeds, are not pulled up until the seeds are ripe.

The fibres obtained when the stalks are pulled at two separate periods are more solid and less supple than when pulled together.

The stem of the hemp, which may grow as high as six feet or more, is hollow inside and only branches out towards the end. The layer containing the fibres ("liber") envelopes the woody tube.

The filaments, which constitute the actual fibre, are from a fourth to a seventh of a millimetre thick; they are between 5 and 55 mm. long. The fibres thus composed are joined together in bundles and are very difficult to separate. The process of separating them in the laboratory is carried out by using a boiling solution of carbonate of soda. They are bound to each other by a lignified tissue. Humidity affects hemp in the same way as it does flax.

Whereas the best flax is found in Belgium, the finest hemp comes from Italy, chiefly from the country round Bologna and Ferrara. The filaments are long, white and of the finest texture, but are relatively less solid than the French or Belgian hemp. The hemp from Picardy is considered the best in France, its fibres are long and silky. The hemp from Champagne is also excellent. That from Anjou and Burgundy is also superior. Russia supplies hemp of ordinary quality.

Coarser varieties of hemp are sold to the rope trade (rope-makers' hemp); while the finer ones, strong, white and flexible, are used for the manufacture of canvas.

INDUSTRIAL OPERATIONS

Drying. — The stalks, after being pulled up, are dried in the sun, which facilitates removal of the leaves. This is done a few days later by firing the plant on the ground. The plants are then made into bundles according to their length, and sent for "rettion".

Rettion. — This operation takes place in rectangular retting pits, about 1.50 metres deep, the water never reaching the top. If there is a slight current (e.g. in a river or large stream) the
operation is carried out more quickly, and in a more regular way. The bundles are carefully arranged in the tank and weighted with planks or stones, or else held under the water by means of poles. The length of time they stay in the water varies according to the quality of the hemp, the temperature of the air and the condition of the water. The difference may be from four to twelve days. The bark peels off at this stage and the textile fibres appear. The retting of hemp may also be carried out as a regular industrial process, using hot water with or without selected microbes.

An enormous quantity of tufts from the hemp stalks falls to the ground; it comprises the coarser debris from the woody substance, whilst the dust flies away above the cylinders.

Hemp, cleaned and laid on a wooden stand, is taken up in handfuls and smartly shaken by a workman at the *silgere* and passed on to the machine, where the second cleansing process takes place. So much dust arises from this process that it is sometimes difficult to see the machine working. The dust is extremely fine and light, and penetrates into the premises and their surroundings.

The season for heckling, which follows that of retting, usually lasts from September to January. The work is generally carried on in rough wooden sheds, open to every breeze. Sometimes canvas is hung up vertically between the feeding rollers and the cleaners to protect the workman from dust.

**Hemp breaking.** Sun-dried hemp, rippled, retted, and again sun-dried by the grower, is sent to the breaking shop, where it is finally dried in coke ovens for about twenty-four hours, after which it passes through two cleansing stages.

The first step in cleansing, carried out by means of a cruscher, or husk-remover, crushes the stems by means of fluted cylinders arranged in layers and turning at a considerable speed. The stems emerge at the end of the machine and are gathered up by a workman whose special work is to draw them out.

Heckling. In small concerns the tow is heckled by hand with a coarse comb, which removes the large hemp stalks and a certain quantity of thick tow. This raw hemp is then sent to the factory and worked up.

The hemp which is destined for the rope trade is combed in order to
clean it and separate it as required. Operations preparatory to heckling are necessary for hemp destined for the spinning mills.

The raw tow is milled, that is to say, it is rendered supple by being passed once more through a machine fitted with fluted rollers, known as a "softener". The hemp is laid flat on these cylinders, which revolve alternately, more in one direction than the other, so as to facilitate the passage of the tow. The interstitial substance and the ends of the hemp stalks which are still adherent, are reduced to dust and to tiny pieces, which are partially beaten out of the tow by means of a

is so far from clean that it would be impossible to submit it in that condition to the carding machine. It has to go through a process of "beating", which is generally carried out in an apparatus fitted with flat blades of wood, revolving in a cylindrical machine, where the material is violently shaken. This apparatus, of whatever type, would produce plenty of dangerous dust if special precautions were not taken.

Carding. — Carding engines used for hemp are known by special names in different centres, which proves that they are more or less specialised, and

sort of wooden sword, called a "tawing-beetle" or "scutch blade".

The hemp, which always has very long staple, is then cut by a machine called a "cutter", which is the same as that used for flax. It is then ready for the industrial heckling and for the following operations: spreading, drawing, roving, and spinning, which are exactly the same as for flax.

Working up coarse tow. — Coarse tow coming from agricultural processes where breaking is carried out, and even that which has undergone the preliminary processes at the factory that in some places the process of carding is divided up. However, the technique of the working of each carding engine is the same as the working of carding engines used for flax. The only difference is that disadvantages are rather more marked for the hemp machine, on account of the greater resistance offered by the coarser material being worked, and special difficulties arising from the abundant production of dust.

Winding, drying, perchng, and bundling are carried out exactly as with flax.
PATHOLOGY

From the point of view of the health of the workers, the working of hemp offers in a rather more accentuated degree all the disadvantages that arise from the working of flax. There are, besides, some extra disadvantages.

First and foremost are the unpleasant effects caused by retting. The workers have to go into the tank either to place the bundles into the water, or to take them out, and this laborious work, carried out under the blazing sun, compels them to wade in water up to their waists, and the whole body, except perhaps for the back, is wet through. The water, especially when the time comes to take out the bundles, is putrid, and contains sulphured hydrogen; its surface is covered with a greenish-yellow slime; it exhalas a nauseous penetrating smell, but the smell goes off if the water is exposed to fresh air, and especially if it is boiled.

When the time comes to take the bundles out of the water, the work has to be done whatever the weather may be.

The workers suffer from a whole series of distresses, according to Savicevic, who analyses them very precisely in his report. First and foremost comes a very general erythema, which attacks the workers who pull off the leaves. It is due to the dust, and is aggravated by perspiration and by the particular movements of the work. This erythema, which is accompanied by itching and a burning sensation, is a slight lesion, but it may act as a portal of entry for other infections.

The legs and feet of the workers are affected with eczema, which is undoubtedly of traumatic origin and may easily be complicated by deep and painful wounds, by irritation, raising and loss of toenails, etc. The doctor is not called in, as a rule, until there are complications. Maceration of the skin is undoubtedly the determining factor of the lesion, which tends to heal quickly if the patient ceases work.

Hemp dust, which is thick and made up of rather coarse irregular and pointed particles, causes irritation of the conjunctiva and the mucous membrane of the respiratory passages of the nose, back of the throat, and pharynx. The incidence of tonsillitis among these workers is high, and calls for notice from the medical profession. This tonsillitis is accompanied by headache, painful deglutition, shivering, and feverishness. In rare cases th-
tonsilitis becomes phlegmonous or ulcerative. But the importance of this lesion lies in the fact that from it may originate such illnesses as rheumatism and endocarditis.

Hemp fever, similar to that of flaxmen, is considered by some experts to be due to the pollen of the plant in the flowering season; other experts think it may be due to the actual dust which acts as a protein toxin (see further). The feverishness appears suddenly, the temperature goes up to 40° C. or even higher, the patient complaining of headaches; an intense dyspnoea is observed, catarrh of the back of the throat, and sometimes vomiting, diarrhoea, and epistaxis. This only lasts forty-eight hours. It is an interesting fact that domestic animals often have an attack of this fever when the hemp is in flower.

In addition, the workers, and especially the women, fall victims to muscular and articular affections, especially to lumbago, and also to neuralgic troubles, both radial and cubital, due to the extremely trying labour involved in retting. The shoulder or wrist are the joints most often affected.

These troubles are common enough among workers employed on the preliminary operations generally carried on in the open air; but they are far more prevalent among workwomen in the factories which are notoriously unhealthy. This is why the workers in the hemp spinning mills leave the factory when summer-time comes and drift away to agricultural work in the open air, in spite of lower wages.

Among the women menstruation troubles have also been noted, and in some cases amenorrhoea, which persisted several years, and was naturally accompanied by nervous troubles, as might easily be understood (Slaviero).

The general opinion is that the harmfulness of this dust is due to the heavy percentage of silicious matter it contains. It does not contain much pectin or gum, which abound in flax and are apt to swell and dissolve in the mucosa of the respiratory passages. In some degree the harmfulness may also be due to the presence of cannabine. Whereas flax fibres, when put through the carding process, separate easily, hemp fibres are much tougher, and the dust which comes from them is derived mainly from the almost complete destruction of the gum-resinous frame of the fibres. The resinous matter, more or less toxic, according to the varying qualities of the hemp, is heated by the action of the rollers in the heckling process and reduced to a soft state; it is freed partly in the form of dust often mixed with sulphur, which in some cases forms on the fibres in consequence of their having been retted too long, or having been retted in stagnant water.

In 1889 L. Salomon (Mans, France) described in detail the symptoms of an illness which attacked the workers of that district who were engaged in heckling hemp, and which he attributed to hemp dust and to cannabine.

A peculiar type of old worker is only to be found engaged in the operation of heckling (especially when the combing is done by hand); he is extraordinarily thin, has an earthy colour, brown skin, wan features, stooping shoulders, wasted limbs, and retracted abdomen (this last is very characteristic).

The beginner who starts work at the factory as an adult rapidly loses flesh and atrophy, which does not go beyond a certain point, particularly affects the muscular system and the intestines. According to Salomon, it is accompanied by an almost complete extinction of sexual desire, and in women by metrorrhagia and abortions. The workers complain of feeling stupid and of violent headaches as soon as they start work in this trade, or on resuming work after the weekly rest, or again at the opening of the heckling season.

The breakers are less affected than the hecklers. The introduction of mechanical hecklers has considerably reduced the extent of hand-combing, and the old heckler certainly represents a type which is doomed to disappear. In 1913 Genet reported only three very slight cases of this cannabine atrophy.

Cases of bronchitis, which may, however, not be reported, are partly due to dust and partly to a nervous cause. It varies in intensity and in the form it takes. The occurrence of eczema behind the ears and on the hands is more characteristic, and is similar to that described in connection with flax workers.

During spinning in a moist atmosphere, the nauseous smell, which is characteristic of this textile, is very unpleasant for those not used to it. A strong feeling of malaise is noticed and this may be accompanied by slight symptoms of intoxication, analogous to those experienced on exposure for some time to the emanations from a hemp field. The workwomen, however, soon become accustomed to the smell, but this does not prove that their health has not suffered.
There are no detailed statistics bearing on this question. The available figures refer rather to work in the rope trade, in which fairly frequent cases of coughs, asthma and respiratory affections are observed. According to the old data furnished by Hirt, 42.3 per cent. of sicknesses are respiratory; according to the more recent data of Hoffman, deaths from tuberculosis account for 25.7 per cent. of all deaths, and deaths from other respiratory diseases for 8.3 per cent.

The introduction of machinery for these very dusty processes has not improved the conditions of these workers, as formerly they generally used to work in the open air. Opening the bales of hemp and the beating are very dusty operations. The use of an emulsion of oil and water in preparing the fibre for carding, and also of colouring matter and tar in the course of the mechanical process of softening the hemp, favours the occurrence of dermatitis.

For particulars regarding the special lesion reported by Kazda (1922) as affecting a workman who used to manipulate a very heavy knife with his right hand—a procedure considered to be the cause of a serious illness which terminated fatally—reference should be made to the original article.

**Hygiene**

The process of retting should be adequately regulated so as to alleviate or entirely eliminate the trying work in the water and slush. The bundles should be manipulated dry, being arranged beforehand in a cylinder and run into the tanks and taken out after the water has been run off. Efforts have also been made to replace the process of putrid fermentation in water by a bacteriological retting, based on the property possessed by certain bacteria of rendering soluble the pectose which makes the fibres stick together and to the surrounding tissue. Mechanical appliances for washing and drawing out the bundles have been tried at Ferrara, but apparently the results up to the present have not been very satisfactory.

As regards work in factories, the hygienic measures are the same as those set forth for the flax industry.

In the workshops where the softening process is carried on, it should be quite sufficient to have general ventilation with a descending current, without carrying off the dust at the point of origin, which would present difficulties. However, it would be useful to complete such ventilation by moistening the air by means of spraying with water. This would keep the atmosphere of the workshop at a high degree of relative humidity and would encourage sedimentation of the fine dust.

The machine for cutting the bundles of hemp, which exposes the workers to the inhalation of the dust, should be enclosed with sheets of metal in the shape of a boat. The upper part of the discs should be covered with a protecting cap. A ventilating fan with moderate pressure should remove the dust, directly it is produced, by a downward current and carry it into a dust chamber.

For the heckling process, see article "Flax".

The beating machines, used to free the hemp from fibrous waste which accumulates under the heckling machines before carding takes place, must be kept clean by means of an exhaust draught with a strong downward current, which places the interior of each cylinder containing beaters under a minus pressure. In this way the dust cannot escape from inside the cylinder. This system is the same for beaters that move with a see-saw movement, or with a rotary movement.

The air driven back by the ventilation is entirely freed of dust by a light water spray.

The carding engines, breakers, mechanical combers and drawing machines can be very effectively ventilated by downward current.

The water used for retting is often a source of pollution to streams and rivers; the black colour and horrible smell it gives off are well known.

For purification of the water, see the article "Industrial Waste Waters".

**Legislation**

In Belgium workers under 14 years are excluded from beating, cleaning, handling and stripping the hemp stalks in workshops where the dust is present.

In France young people under 18 years are excluded from stripping if it causes dust and from spinning where water is not laid on.

In Germany young persons under 16 years of age are excluded from the carding workshops and other places where dust is present.

In Italy boys under 15 years and girls under 21 are excluded from beating, clean-
lug and carding where effective removal of the dust is not assured.

In Japan young workers are excluded from the workshops where the dust is very abundant.

In the Netherlands young persons under 18 are excluded from beating done by hand, etc.

In Spain boys under 16 years and girls under 21 years are excluded from the cleaning process, and beating and carding, which would expose them to dust, and from spinning processes where the necessary measures are not taken for providing a flow of water.

As a general rule legislation is the same as regards hygienic and protective measures for the hemp industry as for the flax industry, which is not surprising considering the similarity of their technology.

In Great Britain, the Regulations of 28 August 1907 lay down special hygienic rules for hemp and jute spinning. These Regulations are evidently based on the Regulations of 28 August 1906, which apply to flax and tow spinning. These Regulations comprise: fixing the proportion of carbon dioxide at 9, 12, 20 parts per 10,000 so as to give a minimum purity under 21 degrees. Artificial humidity; the use of respirators provided a flow of water. 

The hide consists of a dense plexus of fibrous bundles. The epidermis, as well as the keratine, is eliminated in the course of treatment of the skins. The albuminoid matter is prevented from putrefaction by combination with tannin or its substitutes; this operation constitutes tanning.

Before tanning the skins undergo the following processes: softening, depilation, fleshing, and washing with lime.

The hides are placed on the market in the following states: market hides, dry salted hides, or wet salted hides. Market hides are native to the country; the others are almost entirely imported.

After having been freed of the unusable parts in tanyards (clippings), the skins have been soaked for some time in clean water to free them from blood, dung and foreign matter, which soil them. They are then "cleaned" after having been stretched, hair side uppermost, upon the "beam", which is the inclined bench of the tanner, by means of a blunt-edged tanner's knife. Then they are put back to soak in clean water for a variable time; after this they are drained.

Dried skins all come from abroad. Generally they have only undergone treatment by stretching them out under a hot sun so as to obtain as quick a desiccation of the organic tissues as possible.

A certain number of them, however, are covered in the country of origin with ill-defined substances, the preservative nature of which is derived mainly from arsenical compounds. Sometimes, so some tanners say, they contain salts of mercury.

The dried skins—"flints"—arrive at the factories hard and rigid, like panels of wood.

The preliminary processes mentioned above are pretty well all the same, whatever is the later treatment to which the skin is destined; but the tanning processes vary very much.

The hides proper, which are most resistant to water and are destined for the manufacture of boots, belts, etc., are tanned in pits with extractive substances, chrome or synthetic tannins, while the skins intended for making gloves, morocco leather, and for use in orthopaedics are tanned after the manner of tawing and chamoising.

Finally, the preparation of "Hungray leather" is designed to make large skins for harness. The products thus obtained are not real skins because they resist water badly. Further, hides and skins

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The photographic plates have been kindly lent by Mr. Weizman, Factory Inspector, Zurich.

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after tanning undergo processes of finishing: currying, dyeing, etc.

Hides are salted by sprinkling a thick layer of common salt on the skin side. Salted hides are native or foreign.

Foreign hides arriving at the port of importation are spread out on the quay and freed from excess of salt by energetic brushing. Some skins look like fresh skins. In tanneries they are treated in the same way as the skins they resemble most, with this difference, however, that the clear water soak is changed oftener so as to get rid of the salt.

A. — Operations Preliminary to Tanning

The raw skins must be protected against the action of micro-organisms and parasites of all kinds. Practically this preservation is obtained by means of salting the fresh skin, by drying in the air, by liming, by pickling with sulphuric acid and sea salt, used particularly for skins which are going to undergo tawing.

In the case where the hairs are not to be removed, the skins are salted with reduced salt, lime, and oxide of iron which is spread on the flesh side. Treating by "arsenical kips" consists in soaking the skins in a solution of arsenious acid in artesian acid, and drying them. The cleaning and softening of hides has for its object to render them fresh and supple. It is effected by washing in water, combined with vigorous agitation which is done either in drum tumblers (cylinders of wood turning round their own horizontal axis, the current of water arriving by hollow trunnions) or in an analogous apparatus cubical in shape in which the axis of rotation passes through the two opposed apices. Antiseptic substances are sometimes added to the bath — formic acid or carboxylic acid, etc., especially if there is any suspicion of anthrax.

The softening process is accelerated by the addition of certain chemical products such as caustic soda, sodium sulphide, ammonium carbonate, alkaline bisulphites, organic or mineral acids, which have the advantage of preparing the skin properly for later treatment. Softening processes based on blood or stagnating impure water (for pickling) present danger for the health of the worker and are scarcely ever employed.

Fresh or green skins come straight from the abattoirs and are treated as has been described.

Dehairing has for its object to render bare the external layer of the skin — the hyaline membrane. It consists of two operations: an attack on the malphigian layer and on the hair by chemical or bacterial agencies, and the mechanical removal of the epidermal products. When the hair is worth keeping (goat hair, sheep's wool) only the root is destroyed and the rest recovered: this is felting or wool pulling. The skins submitted to this operation are subjected to a special preliminary treatment.

Foreign skins generally arrive at the factory dry and already treated with naphthol. They are first soaked in pure water, then passed to the "failler stocks", which open the fleece and clean it. This operation, formerly done by beating the skins by hand on the wool side, spread out on tables with wooden grids, was not without danger for the workmen. To-day it is done in a machine. The skins are then reshocked and skinned worked over with a blunt knife on the skin side in order to soften and smooth them. For biological dehairing or "swelling" use is made of the liquefying action on the malphigian layer of ferments, which are developed under the influence of heat and humidity. The most primitive method is natural sweating: the skins are simply placed in special stoves. Stoving favours the development of bacteria by heat from furnaces and jets of steam blown in. This is admirably suited for sheepskins and preparation of heavy leather.

In chemical dehairing use is made of alkaline sulphides or sulphides of arsenic ("orpiment") mixed with water and salt. The orpiments (As₂S₃, As₂S₅, As₂S₈) are chiefly employed for skins intended for glovemaking and destined to be tanned. This treatment is carried out in vats provided with agitators (mechanical pits).

When the hair has to be kept, chemical dehairing is done by soaking in limewash. The solvents are applied in the form of a paste by a machine on the skin side. The paste, after a certain length of time, penetrates the skin and attacks the epidermis and roots off the hair without affecting the hair itself.

In the mixed process with lime, or "liming", applied principally to soft leathers, the skin is placed in a series of lime pits, containing lime liquors of increasing causticity. It remains in each pit for about two days. The solutions also contain certain bacteria — amongst them the "hair bacillus". According to Von Euler, the lime selects, so to speak, this hair bacillus which alone is capable of developing and will attack the epidermis strongly. During the operation, mechanical stirring goes on.

Various other processes of liming are in use: carbonate or silicate of soda, ammonium, sulpho-arsenates, etc. The manipulation of skins that have undergone liming or treatment with sulphides may lead to irritation of the skin and burns (see later).

In the case where the hairs are not to be conserved, removal of the epidermal tissue is called "depilation". In its primitive form, this process was carried out over a "beam", a piece of sloping wood in semi-cylindrical form, on which the workman spread out the hide, which he scraped with a blunt knife with two handles. The epidermis and hair were thus removed.

The same work is done on the skin side with a sharp knife in order to get rid of the muscular tissue, blood-vessels and bits of fat; this is "fleshing".

At the present time these operations are done mostly with the aid of machinery. The principal piece of the machine for beaming consists of an iron cylinder with
helicoidal brass blades. These blades are blunt, and brush the surface of the skins in order to get rid of all the debris. The wool falls on an endless revolving table where it is carried by a current of air and by the water which is used to rinse it. Next it is calendered, dried in a tunnel drying stove, and sorted. It then consists of "skin wool" ready for the subsequent processes of washing (see article "Wool").

The machine for "fleshing" is analogous to the one described above, but its blades of steel are kept sharp all the time by a special contrivance. It operates on the skin side. The skins from which the wool has been removed are next washed, "trimmed" — that is, the edges are cut off with a knife — rinsed again, treated with sulphide, washed in running water and fleshed. After rinsing, the skin is pickled (in water acidulated with sulphuric acid to which sodium chloride is added), classified according to quality and size, pressed, freed from the pickle by means of washing in a soda lye solution, and finally sent away to be tanned.

The wool and hair are the by-products which become the raw material for other industries (see articles "Wool" and "Hairs, Bristles and Hair").

The "clippings" are also by-products made up principally of offal from hides and skins after soaking and parts which are not wanted: navel, breasts, ears, extremities of the feet, etc. The clippings are used for making skin glue.

Up to this point in the manufacture, the skins should not be subjected to prolonged exposure to the air, in order to maintain their plumped and elastic state. This is why they are placed to soak after each operation.

The "bate", or cleansing solution, is used to eliminate the lime and other albuminoid substances which have been dissolved and to reduce the plumping of the skin in order to render easier the combination of the skin fibres with the tannin. For this purpose drumming in a lattice drum or cubical rotating box, rinsing, beating, and especially treatment with a chemical which dissolves the lime, is carried out. The substances used are fairly numerous: hydrochloric acid alone or with ammonia, boric acid, sulphuric acid, formic acid, butyric acid, etc.

The lactic acid of fermentation processes \((\text{CH}_3 \text{CHOH CO}_2\text{H})\) is mostly employed either in the form of a solution or as a "brand-drench", a mixture of bran and warm water inoculated with bacteria derived from baths made previously. The fermentation set up produces various organic acids: butyric, formic, acetic, and especially lactic acid, which combines with the lime.

Formerly mating was done with pigeon's or dog's dung, the action of which was an alkaline one and, particularly, a bactericidal one. The "bacilli" have been replaced by preparations containing selected bacilli in a medium favourable to their culture. Substances derived from the pancreas are also employed: enzymes or fermented materials mixed with certain substances: a bacillus isolated from the faeces, resembling the bacillus coli \((\text{Bacillum erodiens of Becker})\), but having the property of attacking albuminous substances. Under the action of the amines of ammonia and the acids developed in the artificial putrefaction, the lime is dissolved and the fibre becomes tender and extensible mechanically by the liberated gases. The commonest of these artificial bates is "cropon", consisting of ammonium chloride, sawdust and pancreatin.

In order that the action of the bate should be uniform, the treatment is carried out in drums or in vats provided with mechanical paddles called "dash wheels". The whole of the processes described up to this point constitute the operations preliminary to tanning \((\text{travail de rivière} in French: so-called because they demand a large quantity of water and are generally carried out by the side of streams). The work converts the hairy skins or pelts into skins or hides ready for tanning.

B. — Tanning

Four kinds of tanning have to be distinguished: (a) vegetable tanning in pits or by means of extracts; (b) tanning with synthetic tanning materials; (c) chrome tanning by the one- or two-bath methods; (d) tanning with alum (tawing or preparation of Hungary leather); (e) tanning with oil (chamoising).

(a) Vegetable tanning. — Tannins are bodies which are often very different from one another, but all behave like weak acids, precipitating the gelatine in solution and yielding an insoluble compound with the substance of the skin.

How this latter operation takes place is not yet properly understood. The action of tannin, however, is admittedly both physical (combination) and chemical (blending of the fibres). Tannins exist in numerous vegetables, but only those of the oak, acacia, mimosa, chestnut, quebracho, sudach and some others are used. Skins intended for vegetable tanning have first to be subjected to the process of plumping, having for its object to cause them to swell, so that they take the tannin well. For this purpose use is made of soured tanning juices in pits provided with agitators. The skins pass through several baths more and more concentrated with tannin. A second process of tanning follows in which the skin is kept for a fortnight in a fairly concentrated tanning solution.

For tanning in pits the skins, separated by layers of crushed oak bark, are piled up in the pits and watered by means of pumps. After three or four months of contact the process is recommenced and repeated again a third time. The total time the process takes, therefore, is about a year. This process, which yields excellent results, holds up, however, a lot of capital. For this reason it is adopted everywhere by tanners who use extracts of oak, chestnut, etc., has taken its place as it is very much quicker. These extracts are
obtained by exhausting the bark, wood or leaves with hot water. The skins are immersed in baths which become more and more concentrated and where an intimate mixing is ensured by mechanical stirring. The operation can also take place in lattice drums.

Some tanneries still employ the pit process, but expedites its operation by a preliminary treatment with extracts or quinone. Others again commence tanning with quinone and end with extracts.

After tanning, the hides are dried by a special machine, the principal part of which is a wheel carrying blades arranged in choppers, taking over the surface of the skin and stretching it. Drying is done in the shade in special places or in stoves.

Use is made, finally, in tanning, of bisulphite eyes coming from cellulose factories and containing the principal ingredients of wood tannings. They must be free from lime.

Goat and sheep skins intended for Morocco leather must retain their natural colour. They are tanned in pits by means of extract of sumach (see later).

(b) Tanning with synthetic tannins.

The substances used in this process are much used for substitutes for tannin than synthetic tannins. Formaldehyde has been used for thirty years and serves for the preparation of washable skins for gloves and orthopaedic purposes. It is used in the form of a solution containing alkaline carbonates in equal proportions.

The "syntans" are tanning substances obtained by condensing formaldehyde with sulphonated derivatives of cresol, naphthalene or anthracene. They are used especially in Germany and Great Britain under the name of "Nerodal", "Ordoval", "Cornal", etc.

The syntans find their use generally in mixed tanning with chestnut and quebracho for Morocco leather and leathers for furniture.

(c) Chrome tanning (for shoe leathers).

In the two-bath process the skin is treated with a hydrochloric solution of potassium or sodium bichromate in a paddle drum. It is then hung up in the air to free it of excess of liquid, then plunged into a reducing bath: hyposulphite of sodium or sulphur dioxide in acid solution. The basic sulphate or hydrate of chrome is formed, which combines with the leather. This operation is repeated if necessary, and exposure to the air.

In the one-bath process the skin is directly immersed in basic solutions of chrome salts generally prepared by treating potassium or sodium bichromate with hydrochloric acid and reducing by starch, glycercine or glucose. The operation is conducted in a paddle drum; sodium chloride being added to the bath. After tanning, the skins are neutralised in a slightly alkaline solution, rinsed, hung up to drain and to be aired and dried.

Both bath tanning with chrome is done by immersing the leather in a bath of alum and tanning with oil. See later under the headings "Tawing" and "Chamois Leather".

C. — Currying

Currying properly so-called comprises a great number of operations of which those most used are as follows:

"Puffing" or "breaking up", which is called in currying "tanning", the object of which is to soften the leather. After sifting in water, when sufficiently impregnated, the skins are spread out over hurdles where they are trodden down by a workman provided with special shoes having very thick soles. For this work also a tool is used (a mass of hard wood with a long handle) or, better still, a paddle drum.

"Buffing" or "shaving", which has for its object to rid the leather of useless skin and give it an even thickness.

"Drawing", which gives the skin its natural grain. It is effected by means of the pommel (a rectangular instrument of hard wood, the lower surface of which is convex and provided with transverse grooves). It is also done by means of numerous machines "for raising a nap".

"Waxing" with tallow or oil. The tallow, heated to 90° C., is applied on both sides of the leather; gently heated, with a woolen brush. Preparation for Hungarian leather this operation is performed in stoves heated to a very high temperature. The making of Hungarian leather, an arduous and unhealthy process, is now often done by machinery.

When the leather has to be subjected to oil "degras" is used, which is a mixture of animal fats and a residue derived from chamois leather. Artificial kinds of degras may also be used, among which it is well to recall the degras made from lead.

For blacking a number of formulas are used, the majority of which are harmless. There is, however, a chrome and an aniline black.

"Waxing" and "finishing" have little interest from a health point of view. Still, it should not be forgotten that in these processes dyes and chemicals are sometimes employed — thus, for example, for red waxing, vermilion; for yellow, chrome yellow; for green, arsenic; for white, white lead.

For "finishing in colour", as a preliminary the skins are dyed without mordanting by means of vegetable or aniline colours, or by metallic salts. Thus the reaction between gelatin and potassium chromate used to obtain a yellow tint; that between acetate of copper and arsenious acid to obtain a green; nitrate of mercury and potassium iodide a red tint, etc. Dyeing is done in vats, in revolving drums or by imprinting.

Varnished (patent) leathers used for making evening slippers (pumps), leather for coach furnishing and saddlery are brilliant and waterproof. A black or coloured varnish is applied. The skins prepared by tanning are first subjected to
dressing (to close up the holes in the skin, to soften it, and to prepare it to take the
varnish), then to several sandpaperings, in
which a risk of lead poisoning is run
because the finishing material, made up
of a mixture of oil, boiled linseed and
various powdered matters, includes some-
times white lead, lead chromate, lead antimo-
mate, arsenic sulphide, copper arsenite, etc.).

In making Hungary leather the tanning
substance is aluminium chloride, which
is obtained by a double decomposition of
sea salt with alum. The operations pre-
liminary to tanning do not differ mate-
rially from those practised in tanyards;
but certain skins are shaved and are not
unhaired with lime. "Aluming" com-
prises as its principal operation treatment
in a vat by treading or, as is usual to-
day, by mechanical treatment.

The dressing with tallow is very un-
healthy if it is done by hand.

Tawing

Kid and lamb skins, used for glove
making, are subjected to a series of pro-
cesses, some of which are peculiar to this
industry. The skins, after reaching the factory
in a dry state, are generally after treatment
with naphthaline, are softened in much
the same way as has already been de-
cscribed for tanning. They are cleaned
with a blunt knife for the purpose of
spreading them out and removing the dirt
(softening and removal of the fatty matter
from the flesh side of the hide). To
remove the hair the skin is covered on the
flesh side with boiled orpiment and lime,
mere rarely with sodium sulphide and lime,
or with some alkaline hydrosulphide
(liming). The skins are piled by twos, skin against skin, and are piled one on
the other ("ageing"). After rinsing, the
skin is unhaired on the beam by means
of a rounded knife. But if they are very
numerous they are treated with a weak
solution of milk of lime ("unhairing").
Fleshing and shaving follow to remove
the useless flesh and the "clippings".

Before bating the skin is filled in a
drum tumbler. As a bate, dog's dung
diluted with water is used, or pigeons' or
fowls' droppings, or guano. Sometimes
drenching with bran follows. The skin
is then rinsed, freed from foreign matter,
and dressed, which is the form which
tanning for glove leather takes. The
"salad" or "sauce" is a thin concoction of
alum, salt, yoke of egg and starch.
Dressing is sometimes done with chrome
sulphate.

The skins are then dried, hardened,
soaked and filled in clear water, then
passed to the stretching machine, which
is a thin, semilunar sheet of steel, blunt
and mounted on a wooden stand. The
skin is pulled to and from across the blunt
edge of the stretching machine. The
thickness of the skin is equalised and the
skin is rendered soft for "dollying". With
this in view the skin side is placed on a
wooden polishing wheel treated with
emery. The skins are tied in bundles, and
skinned. This last work constitutes the morocco leather industry. Dyeing is done either by successive dip-
ing of the skins or by placing them on a
board and applying the colour by means
of a brush. As dyes, aniline or natural
colours are used. When dyeing is done
with fixed colours — these are vegetable
dyes — the skins are mordanted with a
mixture of stale urine and basic carbonate
of soda and ammonia. The table is some-
times covered with sheet lead.

Chamois Leather

In preparing chamois leather the skins,
generally sheepskins, are subjected, after
the wool has been removed, to a series of
operations which are designed to give the
skins a suppleness equal to that of cloth.
At the same time their solidity is pre-
served as much as possible.

The skins, after cleaning and softening,
are placed in lime pits, washed, stretched
and cleaned on the beam: block work.
The skins destined for chamois leather are
then almost always scraped or shaved,
either after softening and cleaning, or
immediately before oiling. By means of
rather sharp tools the epidermis on the
hair side, which is less supple than the
skin side, is removed. This operation is
also done by a machine, which splits the
skin into two parts of unequal thickness:
the outside, which is the thinner of the
two, goes to make morocco leather, and
the thicker one, the fleece side, becomes
chamois leather.

In the preparation of morocco leather
the skins are washed, boiled (with dog's
dung and bran), tanned (with sumach),
dried, dyed and then curried.

In the preparation of chamois leather
the split skins are again subjected to a
fresh liming and then worked on the
beam; they undergo a further washing
and finally are oiled, a discontinuous
operation as it is alternated several times
with a partial drying.

The skin, thus treated, is warmed with
the object of securing more thorough
penetration of the oil into the skin: the
grease is then extracted to remove excess
of oil, which is done by pressure and by
means of warm lyes. The mixture obtain-
ed is the "degras" used in currying.

After degreasing the skins are calendered,
dried and subjected to a finishing process
of the part of shaving with a sickle-
shaped steel knife, the internal edge of
which, more or less sharp, constitutes the
effective part of the tool. Certain skins
are not shaved but buffed or "dolled"
instead. The skins when stretched, graded
and sorted are then ready for despatch.
Chamois leather which is normally brown
can be bleached with sulphurous acid.
Dyeing of Skins

Generally, dyeing is the rule in the case of rabbit skins intended for making artificial fur. More rarely the skins of other animals are used, e.g. hares, etc. (see article * Fur Trade *).

The split skins, scraped and carefully cleaned, are softened in water preparatory to a commencing putrid fermentation. Often a mother liquor is left in the pit, that is, the residue of the action which has taken place previously. The skins are then subjected to fleshing and tanning (with catechu, oak bark). The skins of white hares arrive from Russia already prepared for tanning; they are fleshed and tanned with alum and kitchen salt.

The skins thus prepared are softened (stretched or beaten), degreased, shaved (by machinery), looked over, sorted, and, if necessary, patched.

Dyeing (*lustering *) is effected differently according to the nature of the effect to be obtained, and the technical details attending it are little known. A black colour obtained after repetition is mostly sought after, although chestnut, fawn, etc., are also in demand. The treatment is by soaking in baths or by brushing.

Hydrosulphite or oxygenated water (see article *Bleaching *).

Bignelli (1925) has also drawn attention to the presence of arseniurettd hydrogen gas in tanneries and the risk from it.

Attention should be drawn also to illness from cold among the workmen employed in the processes prior to cleaning and softening; affections of the auditory apparatus among workmen employed in beating the leather with hammers.

Lastly, there is the smell, always disagreeable and sometimes during hot weather nauseating and repugnant, due to the decomposition of organic matters, to the putrid fermentation going on in the cleaning waters, and especially where excrement and putrid urine are used as baiting or mordanting mediums.

**Statistics**

Anthrax is a particularly serious risk for the persons employed in the hide and skin industry.

In Germany the cases of anthrax reported in the industry during the period 1910-1921 numbered 538 out of a total (for all trades) of 1,458 (36.9 per cent.), of which 98 proved fatal (out of a total of 218 fatal cases: 44.9 per cent.). The number of fatalities per 100 cases in the
industry was 18.2. The cases were distributed as follows as regards occupation:

<table>
<thead>
<tr>
<th>Processes</th>
<th>Number of cases</th>
<th>Fatal of cases</th>
<th>Number of deaths</th>
<th>Deaths (per cent.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commerce and delivery of hides and skins</td>
<td>98</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tanning</td>
<td>432</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leather processes (glove-making and boot-making)</td>
<td>8</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

External anthrax is commonest on the head, neck and nape of the neck: 264 times out of 420 cases. This situation also shows the highest mortality: 37 out of 47 fatal cases, especially among men engaged in carrying hides and skins.

In the majority of cases of anthrax, infection has been attributed to foreign hides and skins (93.5 per cent. of the cases).

So far as relates to the nature of the skins, infection has been traced to hides of cattle in 182 out of 425 cases examined (171 were dry hides; 9 salted hides); 2 from horse hides (dry); 79 from sheep skins (63 times from dry skins); 77 from goat skins. Thus 313 out of 340 cases (92 per cent.) were caused by dry hides as against 79 only (8 per cent.) from salted hides.

From 1922 to 1925 the cases of anthrax due to the manipulation of infected hides and skins numbered 112, of which 19 were fatal out of a total of 532 reported cases, 90 of which were fatal. Amongst the cases referred to above, it should be noted that cases among workmen engaged in transport (such as dock labourers, etc.: 43 cases with 17 deaths) have not been included.

During this period, the cases of anthrax in German tanneries may be distributed, according to Rebentisch, as follows: 12 (5 fatal) in 1922, 20 (2) in 1923, 20 (0) in 1924, and 59 (4) in 1925.

If the period 1906 to 1925 is taken into consideration, then the German tanning industry, employing, according to Rebentisch, in 1,730 premises about 37,274 workpeople per annum, has reported 648 cases of anthrax, of which 98 have been fatal (1 case per 53 premises and per 1,153 workmen). The proportional rates are, therefore, 3.2 cases yearly: 1.87 per 100 premises yearly; 0.87 per 1,000 workmen yearly.

The deaths show an annual average of 4.9, with relative rates of 0.28 per 100 premises annually; 0.13 per 1,000 workpeople annually.

Out of 100 cases the lesion was situated on the neck or head 66.5 times, and on the upper arm 26.7 times (that is, 93.2 per cent. in all); in 1.5 per cent. it was a question of intestinal anthrax.

In 95.7 per cent. of the cases, the diagnosis was made by the doctor (59.1 by clinical examination, 36.6 by clinical and bacteriological examination).

If the different circumstances under which anthrax occurs are analysed, the following rates are obtained:

### Origin of the hides and skins

<table>
<thead>
<tr>
<th>Origin of the hides and skins</th>
<th>Number of cases</th>
<th>Number of deaths</th>
<th>Number of cases</th>
<th>Number of deaths</th>
<th>Number of cases</th>
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<tbody>
<tr>
<td>Native</td>
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<td>16</td>
<td>1</td>
<td>3.15</td>
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<tr>
<td>Foreign</td>
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<td>45</td>
<td>20.4</td>
<td>118</td>
<td>21</td>
<td>17.8</td>
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<tr>
<td>Uncertain</td>
<td>83</td>
<td>17</td>
<td>20.3</td>
<td>506</td>
<td>13</td>
<td>6.33</td>
</tr>
<tr>
<td></td>
<td>308</td>
<td>63</td>
<td>20.5</td>
<td>340</td>
<td>35</td>
<td>10.3</td>
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### State of the hides

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<th>Number of deaths</th>
<th>Number of cases</th>
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</tr>
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<tbody>
<tr>
<td>Wet salted</td>
<td>24</td>
<td>4</td>
<td>16.7</td>
<td>19</td>
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<tr>
<td>Dry</td>
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<td>45</td>
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<td>165</td>
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<td>25.0</td>
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<td>13.9</td>
<td>159</td>
<td>11</td>
<td>7.2</td>
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### Processes

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<th>Number of cases</th>
<th>Number of deaths</th>
<th>Number of cases</th>
<th>Number of deaths</th>
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<td>Warehouse, transport</td>
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<td>9</td>
<td>26.5</td>
<td>62</td>
<td>6</td>
<td>9.7</td>
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<tr>
<td>Cleaning and softening</td>
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<td>18.4</td>
<td>127</td>
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<td>8.1</td>
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<tr>
<td>Unhauling</td>
<td>104</td>
<td>21</td>
<td>20.2</td>
<td>75</td>
<td>4</td>
<td>5.3</td>
</tr>
<tr>
<td>Tanning</td>
<td>30</td>
<td>10</td>
<td>26.6</td>
<td>22</td>
<td>1</td>
<td>4.5</td>
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<td>9</td>
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<td>58</td>
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### Before unhauling

<table>
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<tr>
<td>Unhauling</td>
<td>136</td>
<td>25</td>
<td>19.4</td>
<td>163</td>
<td>15</td>
<td>9.1</td>
</tr>
<tr>
<td>After unhauling</td>
<td>53</td>
<td>9</td>
<td>16.9</td>
<td>45</td>
<td>3</td>
<td>6.7</td>
</tr>
<tr>
<td>Not specified</td>
<td>103</td>
<td>26</td>
<td>25.2</td>
<td>108</td>
<td>15</td>
<td>13.9</td>
</tr>
</tbody>
</table>

The following rates are obtained: 14.8, 19.7, 29.7, and 28.8, respectively.
If the number of cases is considered in relation to that of the persons attacked per tannery it works out that during the period 1912-1914, of a total of 125 tanneries 92 reported a single case, 17 two, 5 three, and 4 more than four cases.

If the cases are classified according to the processes in which they occurred it would appear that, of 430 reported cases between 1910 and 1921, 152 (with 30 deaths) were reported between 1903 and 1905; 4 cases all fatal in 1910; 12 in 1912; 6 cases "prior to 1918"; 1 case in 1922.

In Belgium from 1899 to 1920 50 cases of industrial anthrax were reported to the Factory Department. Among these 35 occurred amongst brushmakers and 4 in the horse-hair trade; 16 in the tannery industry.

In the enquiry made by Gilbert, to which the reader is referred for further details, the state of health of the persons employed in the hides and skins industry was as follows:

The very interesting details relating to all persons employed, the circumstances likely to influence their health, such as housing, age, age at commencement of work and heredity, cannot be dealt with here.

In Denmark 2 cases of anthrax occurred in 1921 in tanning; no details are given. The only point known was that the infected hides came from South America.

In the United States 15.2 per cent. of all the deaths of tanners (1909) were due to pulmonary tuberculosis: 14.3 to diseases of the heart; 8.8 to pneumonias; 8.7 to chronic nephritis, etc.

An analysis of 123 cases of anthrax in the hides and skins industry in Pennsylvania from 1910 to 1921 inclusive was made by H. F. Smyth and E. Bricker. The number attacked was 12 per cent. of the number directly exposed to risk. The mortality rate among the 123 cases was 21 per cent. During the five years for which the authors had the requisite data, the annual mortality was 2 per cent. of
the number of persons handling the raw hides and engaged in liming. The infected skins came from Texas, Mexico, China, India, South America, as well as the various regions from which goat skins come. The presence of the anthrax bacillus was proved either in the dry or salted hides.

In the State of New York during the period 1911-1919, 23 cases of anthrax were reported, of which 13 proved fatal; 10 (4 fatal) occurred in the hides and skins industry. Hubbard and Jacobson, in the course of an enquiry made in New York in 1920, found 34 cases of anthrax which had been notified in twenty-one months; half of these cases had been caused by the use of shaving brushes. Of 84 cases of anthrax (16 fatal) notified between 1912 and 1920, 58 (8 fatal) affected tanneries and hides and skins warehouses. From 1921-1922 only 1 case was found in the tanneries, out of a total of 4 cases for the whole occupation.

Osborn reported in 1920 several cases in the State of Massachusetts among persons coming into contact with hides and skins. In the course of the year 1926-1927, 51 cases of anthrax (15 fatal) notified between 1912 and 1917, 51 cases of occupational disease were reported amongst the tanners (out of a total of 247 cases of diseases for the whole industry).

In the State of New Jersey during the period 1911-1919, 45 cases of anthrax were reported, almost all in the town of Camden, which is a great centre of the hides and skins industry.

An enquiry by the Bureau of Labour Statistics, based on 592 replies to a questionnaire, revealed the fact that in 19 factories, during a period of two or three years, 70 cases of anthrax were reported. Between 1910 and 1917 the Bureau had knowledge of 293 deaths from anthrax, 42 of which had had their origin in infected hides and skins.

In France between 1912 and 1922, out of a total of 443 cases of anthrax 261 (58.9 per cent.) were found to have occurred in the hides and skins industry. The Bulletin de l'inspection du travail gives the following information as to the distribution of the cases according to the nature of the materials which had given rise to the infection, the country of origin, condition of the materials, etc.:

Goat and kid skins had caused anthrax 142 times; goat and calf skins, once; buffalo hides, 5 times; ox and cow hides, 26 times; sheep and lamb skins, 52 times; dried skins, 18 times; raw hides and various, 17 times; leather, twice.

For a total of 443 cases the incriminated countries were Spain and Portugal, 79 times; France, 14 times; Mediterranean basin, 44 times; Russia, 7 times; Asia 12 times; India 19 times; China 12 times; Indonesia and China and Java, 21 times; South America, 38 times; Africa, 56 times; Australia, 4 times; Siberia, 4 times; etc.

For the same total number of cases, infection occurred when they were in the raw condition 401 times, and when they had been washed and disininfected in 20 cases. In 6 cases they had undergone one of the various industrial processes (tanning, dyeing, degreasing); 10 cases were doubtful.

The districts where the most cases occurred were, on the one hand, Marseille, because of the large number of hides imported there, and, on the other, St. Denis and the department of the Tarn, which are the principal centres for tanning and wool pulling. As a matter of fact, 335 cases (75.6 per cent.) out of the 443 mentioned occurred in these three districts.

The 261 cases in the hides and skins industry were distributed according to the industrial process as follows: commerce and handling, 34; wool pulling (sheep-skins), 34; tawing, 143; tanning, 46; preparation of morocco leather, 2; currying, 1; dyeing, 1.

At Mazamet (Tarn), which is perhaps the most important town in the world for wool pulling, only 14 cases have been reported between 1910 and 1922, or about 1 per annum. In a factory in St. Denis where 13,000 goat skins are treated daily, 63 cases were known to have occurred in five years (1905-1909), among 56 workmen (of whom 25 were children) employed in clipping 12 skins; 46, or 9 per annum, of these cases affected children, for whom the annual morbidity rate was 36.5 per cent., as contrasted with 11 per cent. in the case of adults employed in the same factory.

Among 33 workmen engaged in the manipulation of skins with the hair or wool on, the morbidity was 7.9 per cent.; in the other workrooms of the factory, with 1,630 persons employed, no cases occurred.

The Hospital of St. Denis between 1875 and 1911 treated 424 cases of anthrax, the localisation of the pustule being on the head 135 times, on the arms 52 times, neck 46, trunk 4, and legs 4 times. The number cured was 223 out of 242 cases treated.

In 1923, out of 79 cases reported (9 fatal), 29 occurred in wool pulling, 19 in tawing and tawing, 4 in wool pulling and tawing, 2 in trading skins, and 6 in different industries and processes involving handling of hides and skins.

In Great Britain, the cases of anthrax in the hides and skins industry numbered 441 (out of 1,514 reported cases or 29.1 per cent.) during the period 1899 to 1926. The total number which recovered was 376 and the number of fatal cases 65. The percentage of the latter to the notified cases is therefore 17.3. In 1926 only 9 cases were met with out of 31 for all industries.

The detailed statistics make it clear that for the period 1911-1922 as compared with that for 1899-1910, there had been a slight increase in the number of cases, but a remarkable fall in the mortality rate.
Ox, cow and buffalo skins have caused more cases than have those of sheep and goats. The cases of anthrax from 1900-1926 (Annual Report of the Chief Inspector of Factories) show that workers engaged with animal matter in certain countries are much more likely to convey infection than others. These figures do not include cases of infection due to bundles of mixed skins which consequently would be of uncertain origin.

In Italy Corradi had found in 1890 that of 153 cases treated in a hospital at Genoa between 1887 and 1890, 117 were due to work involving contact with animal matter (34 tanners, 65 dock labourers unloading hides and skins, 12 men employed in the hides and skins industry). Among the remaining persons attacked 22 were butchers and agricultural labourers and 12 sailors.

In Tuscany at Santa Croce on the Arno, 19 out of 24 cases were due to work with skins. In Piedmont Bormans showed in 1904 that from 1891 to 1903 of 58 cases of animal anthrax in the neighbourhood of Turin 56 came from farms, the meadows of which were irrigated by residuary water from tanneries. The increase in the anthrax cases is practically confined to regions where the discharge, transport and manipulation of imported skins is carried on (Genoa and Tuscany).

In the Netherlands the number of cases of anthrax reported between 1898 and 1911 in the hides and skins industry of Western Flanders was only 47, of which 4 were fatal. All of them, except one in 1908 and another in 1909, occurred among tanners. As the number of persons employed remained practically the same and was 1,180 in 1912, the average number of cases per 1,000 workmen was 4.7, of which 0.3 were fatal. No recent statistics are available.

In Russia an enquiry was made in 1955 by Listengarten in fifteen hides and skins factories. Tabretznik, Below, Schakowitsch and Gerasimow also carried out an enquiry in a large leather works, which showed that the proportion of carbonic acid gas and sulphuretted hydrogen and the humidity rate were very high; that the muscular work was extreme; that contact with the suspected material exposed the workmen to anthrax, affections of the skin and subcutaneous tissue (13.4 per cent.), especially in the course of operations preceding cleaning and softening, while among tanners the rate was 30.59 per cent.

In examining the air of Russian tanneries, Butki found the following proportions:

<table>
<thead>
<tr>
<th>Source</th>
<th>Sulphur Dioxide</th>
<th>Sulphuretted Hydrogen</th>
<th>Ammonia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dehairing</td>
<td>0.025</td>
<td>0.34</td>
<td>0.010</td>
</tr>
<tr>
<td>Tanning</td>
<td>0.092</td>
<td>0.56</td>
<td>0.007</td>
</tr>
<tr>
<td>Chrome tanning</td>
<td>0.096</td>
<td>0.60</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Ventilation being better during the months of October and November, the proportions were more favourable.

Two fatal cases of poisoning by sulphuretted hydrogen gas were reported from a Russian factory in 1924. The proportion was between 0.045 and 0.088 per cent. in the effluent; in the air it was from 0.24 to 0.25 mg. per litre.

The presence of these gases and the injury caused by them to the workmen were described in 1910 by Guido Pieraccini. This expert recalled the fact that with the old processes the workmen suffered from "water itch" (lime), but that after the introduction of machinery and tanning extracts the workmen were no longer exposed to the action of lime and to the causes of serious fatigue, but showed digestive troubles and various lesions, probably due to sulphuretted hydrogen gas. Acute cases of poisoning have been produced by the gas escaping from the effluent.

**PATHOLOGY**

The pathology of workmen employed in the hides and skins industry is characterised by two diseases: anthrax and dermatitis.

The reader is referred to the article "Anthrax" for the pathology relevant thereto. The frequency of this infection has been shown above, and it is known besides that hides and skins are the source of the majority of cases of anthrax infection. This, indeed, not only constitutes a menace to tanners but to any workman who for other reasons comes into contact with hides and skins: transport workers (on sea, river and land, etc.), workmen who manipulate hides and skins (boot and shoe makers, harness makers, furriers, soldiers, etc.). Cases have been cited of horses that have worn harness made from anthrax-infected hides. Lastly the effluent from tanneries represents a serious danger of spreading the spores because they infect the meadows on which cattle graze. The hay from these fields has
set up cases of anthrax among the cattle eating it.

Less frequent are cases of glanders. It will suffice here to recall that poisoning induced by compounds of mercury, arsenic and lead, which are used in the industry and of which the clinical picture in no way differs from that generally recognised. Dusts may also give rise to bronchitis or tuberculosis, but more especially may act as the vehicle for conveyance of toxic substances which enter the organism by the respiratory tract and in this way facilitate the occurrence of poisoning.

Rheumatic symptoms and arthritis should also be mentioned, as being fostered by work in a damp atmosphere. Formerly the handwork was carried on in an antiphysiological position and prepared the soil for the development of adenitis, orchitis, etc. To-day, however, machinery has greatly reduced the importance of this cause of injury, the existence of which is even denied by some authorities.

A more important cause of injury at the present time is contact with corrosive liquids. Certain lesions also are particularly liable to occur among those employed in processes preliminary to cleaning and softening: frequent infection of insignificant cuts and scratches; conjunctivitis and lesions of the cornea, most frequently due to contact with fingers soiled with irritant of putrid matter.

Local lesions are due to irritation from the raw materials: lime, arsenic, chrome, etc. Care must also be taken in dealing with the depilatory pastes, often arsenical, the action of which may sometimes resemble in appearance with boil or syphilitic ulcers.

The lesions from chromates are more frequently set up by the two-bath than the one-bath process. For a long time the most important lesion has been known under the name of "chrome hole". This takes the form of a circular ulcer from 2 to 10 mm. in diameter, at the full stage of its development, with undermined edges and an inflammatory border all round. The depth of the ulcer varies; exceptionally it can penetrate the tendon sheaths to the periosteum. Generally the chrome hole is not painful, although sometimes it is so painful as to make the patient scream. Prognosis is favourable provided the workman gives up his work for some days.

Chrome holes are certainly due to caustic agents, so that it is not out of the question of this occupation, in which however it is most frequently found. The affected workman should be transferred to another job and preferably to drying, because, in the opinion of works managers, manipulation of skins coated with "salad", alum, starch, yolk of egg, favours rapid cicatrization (Gilbert).

Klebanoff and Emdin (1927) reported a lesion at the free edge of the nails among tanners. The free border corrodcs and becomes friable and small painful ulcers appear situated on the tips of the fingers. These lesions commence from the early days of employment; they bear no relation to the length of employment and disappear if the workman gives up his job. They are attributable to both a chemical and mechanical action. The wearing of indiarubber gloves is very useful.

A similar lesion has been described by Gilbert in dyeing skins for fur (see article "Fur Trade").

Julien described in 1902 an ulceration of the interdigital spaces and lateral surfaces of the toes in certain men engaged in tanning who, with bare feet in warm water, pulled tanned skins intended for dyeing.

Account must also be taken of the action of chromates on the skin. Continuous manipulation of tanning substances and iron implements dyes the hands a dark colour. To get rid of it the workmen use water acidulated with sulphuric acid. In a Netherlands report for 1913, an account is given of an accident due to burns on the hands from the use of this acid.

In dyeing skins for glovemaking, Gilbert deprecates the use as a mordant of decomposing human urine. This method has not entirely disappeared in spite of the possibility of substituting chemical mordants for this objectionable mixture.

Lastly, the use of dyes with a para-phenylendiamine basis is the cause of dermatitis and attacks of asthma (see the articles "Fur Trade" and "Paraphenylendiamine").

**Hygiene**

The industry of hides and skins has adopted in modern times a technique so different from the old as to give it quite another character.

The number of men employed has diminished and the industry has become more and more centralised. The progress in mechanical and chemical science, as applied to modern industry, is causing a rapid disappearance of the old tanneries which used to swarm over the country.
Although some processes still constitute a menace to the health of the workmen (from such causes as cuts, erythema, and dermatitis), the use of rubber gloves or fingers and the use of tongues and crooks in liming to draw the skins from the pits tender them much less dangerous.

Machinery such as that for degairing, fleshing and finishing, etc., is replacing hand labour more and more.

In tanneries, tanning exclusively in pits is out of fashion, with the exception of the manufacture of a certain quality of heavy leather.

An account has already been given in the technical part of the advantages of tanning with vegetable extracts and chrome. Workmen engaged in chrome tanning should wear gloves or fingers.

The use of a mechanical winch is very useful in the work of withdrawal from the pits, as it largely prevents slipping into the pit.

All the continuous operations are carried on for the most part by machinery, thus abolishing most of the processes of stretching and spreading on tables or carrying.

Machinery is now used for exposing the skins to the air, for pressing, hydro-extracting, smoothing by rollers over a table, for buffing, bleaching, stretching, polishing, lustering, for tannelling, graining, shagreening, beating, calendering, etc. Several types of splitting machines are today at the disposal of manufacturers. In tawing, machinery is used for removing the fatty matter from the flesh side, for washing, for cleaning and freeing the skins of the dirt which clings to them. Similarly, degairing and fleshing is done by machinery, thus doing away with most of the work formerly done by beaming. Although some manufacturers are slow to use machinery, machines do exist for the removal of the wool from the sheepskin.

![Fig. 55. Wearing of gloves during operation of fleshing skins.](image-url)
the same time the slope should not be too great, in order to avoid the risk of the workmen falling. Such wood as is used should be covered with plaster. The waters should be carried away by means of underground channels or removed in watertight drums. The raw hides and fresh skins should be removed before any putrid emanation has occurred. Skins that are going bad or have been removed from the backs of diseased animals should not be worked. Fresh skins might well be treated by processes for abolishing or retarding putrefaction.

The quantity proportionate to the daily needs should be dealt with rapidly. Putrefying matter should not be allowed to accumulate and precautions should be taken as to the storage of clippings, etc.

Horns should be stored in a place set apart for the purpose and they should be removed every two or three days. The premises should be frequently washed down with a hosepipe, or what would be better, with chlorinated water (chloride of lime). Precautions should be taken against vibration and noise and all unnecessary noise and vibration suppressed.

All work giving off foul smells should be carried on under hoods provided with exhaust ventilation, and preferably in closed apparatus provided with exhaust for the removal of dust, gas, etc.

The beating of leather by means of hammers should, as far as possible, be done without allowing the tools to abut on to partition walls; if this is not possible, other measures against noise should be adopted.

The washing water and effluent should be purified before being allowed to run into streams, by sedimentation in pits provided with grills of different sizes arranged in series and cleaned periodically.

When patent leather factories are in question, not only should the causes of harm from dust raised in dressing and the smells given off from the skins and varnishes be dealt with, but also the risks from fire (stoves, varnishes, etc.).

Buildings should be constructed of incombustible materials, should be well ventilated, and provided with ample daylight. The stoves should be of fireproof materials, with iron doors, and separated from the other parts of the workrooms. The furnace should be outside the building; the boiling of oils should be carried on in a separate building of fireproof construction and with good daylight. The boilers for the oil should be provided with a movable hood of sheet iron, capable of being lowered so that in case the liquid accidentally catches fire.

The waters should be cooled and neutralised before they are directed into the sewer.

The essences, oils, turpentine, etc., should be kept in an isolated place, constructed of cement and kept closed. It would be useful to keep a supply of sand near the boiler house.

Personal hygiene. — Clogs, leggings, aprons, etc., waterproof gloves, rubber fingers, goggles, etc., should be provided for the workpeople. Mention has already been made of different kinds of apparatus allowing machinery to replace manual labour. The carrying of dry skins on the back should only be permitted with protection afforded for the head, nape of the neck and shoulders, in the shape of a tight-fitting cloth hood which should be disinfected every day.

The workmen should be examined every day, so as to remove from work any showing uncovered abrasions or cuts on the skin, especially of the hands, arms and neck. First aid should be organised so that immediate medical assistance is rendered in even suspected cases of anthrax. Anti-anthrax serum should always be kept on the premises or should always be available in the local hospitals, dispensaries, etc.

Disinfection of Hides and Skins

Although statistics show a noticeable falling off in the number of cases of anthrax, the hides and skins industry always causes a very serious number of infections.

The part played by foreign skins in causing anthrax is always difficult to determine, because, in a very high percentage of cases, the source of the contaminated skin cannot be ascertained. It is most probable, however, that foreign skins are the most frequent cause of anthrax infection, and that, during storage, by contact with native hides, the latter become the means of disseminating germs introduced by the foreign skins.

Whether this be so or not, it is certain that the incidence of anthrax among tanners, dock labourers, etc., is directly proportional to the import of foreign hides and skins.

While on infected hides and skins endangers, as has already been said, not only the workmen, but also cattle
in the neighbourhood and consequently the agricultural labourers. Without doubt anthrax spores are carried away in the effluent so that introduction of infected hides into a country brings with it infections germ which are disseminated among the flocks through the tannery effluent, whence the vicious cycle of agricultural and industrial infection; hence the importance of combating anthrax in tanneries to protect the agricultural population, the live stock and to ensure greater success of veterinary police measures.

On arriving in port the salted skins are brushed right on the quay (in certain countries by women), sprinkled with a little salt, rolled up again, and forwarded. The dried skins arrive on the contrary in rough packages of 25 to 30 skins. They are lifted by cranes, less frequently carried on mules inclining on cradles and mules to be taken to the warehouse or railway wagons. They are therefore little handled. As complete a protection as possible of the workmen engaged in transport is called for, because it is very difficult to apply practically disinfection of the hides.

If the incidence of anthrax cases in the industry is analysed, it is found that the majority of infections are produced before cleaning and softening. In Germany and France these cases occur especially in the operation of washing and liming: in the United States and Great Britain in the course of transport, warehousing and sorting.

Certain experts hold that the problem of disinfection of skins would be simplified if it were possible to disinfect the surface of the skin successfully, because the anthrax spores are found principally on the surface mixed with dirt and dung adhering to the skin. Anthrax in the tannary will not be eradicated until an effective method has been found of destroying the anthrax spores without injuriously affecting the quality of the leather—a method which is, at the same time, sufficiently economical and practical to be put into general practice.

In 1933, H. F. Smyth and Pike, of Pennsylvania, studied experimentally the action of iodine vapour on hides artificially infected with anthrax. The process proved only of a large in laboratory research, but according to these investigators, iodine is not only an excellent disinfectant for anthrax spores, but in no way destroys the skins subjected to its action. Disinfection may be done either with iodine vapour or with iodine in aqueous solution, or dissolved in volatile products such as carbon tetra-chloride or a mixture of carbon tetra-chloride and light carbides (a process, however, less practical and more expensive than disinfection by vapour).

Goertler has again taken up, in 1926, experiments on the action of iodine on anthrax spores under conditions similar to those in tanneries. The germicide action of iodine is less than it was thought to be since in practice other factors such as alkalinity, the amount of salt, water, the albumins, the fat, the temperature, the cohesion, the adherence, etc., play their part.

Up to the present, three processes have been recommended: that of Seymour Jones, that of pickling, and the soda lye or Hailer process. These are described by Leymann as follows:

(a) The Seymour Jones process consists in dipping the suspected hides and skins into a solution of 0.6 per cent. of iodine (mercury chloride) and 0.9 per cent. of formic acid and leaving them for twenty-four hours. Experiments made in Germany, more especially some conducted by the Federal Office of Health, show the process to be of little avail. It was proved impossible to rid infected skins of anthrax spores by treating them with a solution of the composition mentioned, even when left in that solution for as long a period as seventy-two hours. Hilgermann and Marmann have proved by means of culture the presence of live anthrax spores in hides which had been treated by the Seymour-Jones process after the sublimate which was still attaching to such hides had been removed by means of sodium sulphite solutions.

More favourable results, however, are to hand from the United States. Its efficiency is said to have been proved by Tilley, who found, herein agreeing with the experiments conducted by the Federal Office of Health, that the Seymour-Jones process was not efficacious against anthrax spores when conducted in conformity according to the instructions laid down.

On the other hand, however, he found that no further growth of spores took place when culture or inoculation was attempted, provided the hides were not cleansed of the mercury salts immediately after having been lifted out of the sublimate solution, but if before cleaning a period of several days had first been allowed to elapse.

Accordingly, the regulations of the Bureau of Animal Industry of the United States permit the use of the Seymour-Jones process under Joint Order No. 2 of the Treasury Department and the Department of Agriculture dated 1918, covering the handling of anthrax infected hides and skins on condition that no further process shall be undertaken until a fortnight has elapsed from the time when the hides were treated with sublimate solution.

This point is of great importance. If the hides are kept in a state of dampness...
during this fortnight they become impregnated with the sublimate solution and its effect on the anthrax spores continues, and spores which are not very resistant hereby lose their reproductive faculties. It is, however, very doubtful whether spores which are of great resistant power, do so. Gegenbauer (1921) has proved that anthrax spores of resistant power only die after the expiry of a period of 100 days when the sublimate solution varying between 0.05 and 3.0 per cent.

The same expert was able to prove that spores were still capable of reproduction as soon as the sublimate attached to them had been either removed or neutralised by means of weak solutions of hydrogen sulphide or other sulphides. It is quite likely that a similar chemical process takes place in the tanneries; for it is very usual, in order to remove hair from hides and skins, to lime them with solutions containing sodium or calcium sulphide. On all these accounts it would therefore appear doubtful whether a treatment with sublimate solutions according to the Seymour-Jones process can be considered in vain. The object, on the basis of having the hides stored for two weeks after the process has taken place, especially in view of the fact that the hide itself neutralises a very large part of the sublimate solution, is that the sublimate which has been absorbed has a certain bacteriological effect on the spores which causes them to die. This bacteriological effect was experimentally proved for the first time in connection with the treatment of anthrax spores with formaldehyde solutions (Hailer). The process may take effect after treatment with sublimate solutions, but the fact has not yet been proved with certainty. The Seymour-Jones process, therefore, is still viewed in Germany with some scepticism.

(b) The pickling process was first experimentally worked out by Schattenfroh (1911) and by Gegenbauer and Reichel (1913) in Vienna. The process consists in treating infected hides and skins with a solution of 1 to 2 per cent. of hydrochloric acid, to which 10 per cent. of common salt has been added, and which is kept at a temperature of 20°-40° C. In calculating the amount of hydrochloric acid to be used, it must be remembered that the hides themselves absorb a considerable amount of it and therefore remove it from the solution; the amount used must therefore be increased proportionately. The time taken by the process depends on whether a 1 or 2 per cent. solution is used and on its temperature. In the German Federal Office of Health experiments on ox-hides, calf-hides and sheep-skins, it varied between nine and forty hours.

When the pickling process is ended the hydrochloric acid still present in the hides has to be neutralised. For this purpose a 3 per cent. soda solution is used. The hides are moved up and down in it. After this they are at once ready for further processes of salting and stockling.

The addition of 10 per cent. of common salt to the solution is of special importance. This addition not only greatly increases the bacteriological effect of hydrochloric acid on the anthrax spores, as stated by Schattenfroh, Gegenbauer and Reichel, but also decreases the injurious effects of the hydrochloric acid on the organic substances in the hides.

The destructive effect of the solution on the anthrax spores can be increased by raising the temperature to 40° C. without any injury to the hide treated, more especially as the time taken in the process can then be proportionately reduced. On the other hand, the temperature of the bath must not sink under 20° C., as otherwise the solution becomes too thick to allow the baths to be placed in rooms the temperature of which is liable to fall below 20° C., special arrangements must be provided for heating. Gegenbauer and Reichel recommend that the solution should be kept at a constant temperature of 40° C. in order to make the process more certain. The writers are of opinion that the pickling process gives good results. The experiments, however, were conducted on a small scale and no final judgment was possible as to whether the pickling process had any effect on the quality of the leather prepared from the hides so treated.

Factory experiments conducted under the direction of the German Federal Office of Health, in agreement with the Skin Testing Institute in Freiberg, have proved that ox-hides and calf-hides can be pickled without any apparent injury. In the case of goat and sheep skins, on the other hand, it has been, to a great extent solved by large-scale practical experiments at Vienna. Frequent outbreaks of anthrax had taken place in that city, occasioned by the working up of parcels of hides, and bacteriological examination had shown the presence of anthrax spores in these parcels. The manufacturers were, therefore, instructed that they must either permit the whole load to be destroyed, or must agree to have it disinfected at their own cost, by the pickling process; they chose the latter. The result was to show that the pickling process, when properly carried out, has no bad effects on the quality of the leather.

On the other hand, it became clear in the course of further experiments that it was absolutely necessary to keep strictly to the directions laid down. Among the points to be noted is the keeping up of an even concentration and temperature in the solution used. There is no great difficulty in the case of large and properly conducted works or in special disinfecting stations, but smaller factories do not find this very easy. The mere keeping up of
an even temperature for the pickling bath requires very great attention and may, in particular, be avoided. This is only in those establishments where special acid-resisting plant and heating apparatus has been installed.

It takes place immediately after the hides are unpacked and before the tanning processes are started. Hides which have been subjected to pickling can, as soon as neutralised, be sent forward for the normal process of further manufacture, or, alternatively, can be salted and stocked, or again forwarded as soon as neutralised, be sent for- 

tanning. The basis is a 0.5 per cent, soda lye to which salt has been added, or, alternatively, can be salted and stocked, or again forwarded elsewhere. The pickling process would seem to be especially suitable for the disinfection of imported hides and skins in special establishments at the ports of entry or at industrial centres: it is, in fact, the only process which is suitable for disinfecting under these circumstances. It appears to be equally efficacious for every species of hide or skin, nor is its cost very high.

c) The lye process, or lixiviation, was invented and developed by Hailer (1915), of the German Federal Board of Health. The basis is a 0.5 per cent, soda lye to which 1 to 10 parts in 100 of common salt have been added. This has a strong destructive effect on anthrax spores. Indeed, the disinfecting power of caustic soda solution was previously known.

Experimental work on the pickling process had proved that the addition of common salt neutralised the injurious effect of acid solutions on hides and skins, while at the same time it increased the destructive power of the pickling solution on the anthrax spores. Experiments were accordingly made to prove whether such an addition of common salt would have the same effect in the lye process. They showed that it is possible to attain a sufficient grade of disinfection by the use of soda lye to which salt has been added over a practicable period of time, namely, from 72 to 96 hours.

Use had already been made of soda lyes on ox-hides for the same or even stronger effect in order to full up the hides and skins in the course of the practical processes of manufacture. The process did not in any way injure the material. It was, therefore, not unnatural to assume that soda lyes mixed with common salt could feasibly be used for the disinfection of hides and skins without any injurious effect, and experiments so far conducted have confirmed this assumption.

In practice, it will apparently be possible to use the lye process in more than one way. It will either form an entirely separate process, as is the case with the pickling process, or else it may be related to the actual processes of tanning and may replace, either in whole or in part, some of the stages of tannery. For instance, the stage at which the material is limed and perhaps even the softening process.

If used as a separate process there is no particular advantage as against the pickling process, in general, perhaps the fact that acid-resisting plant is not necessary, and that the lye solution need only be kept at a temperature of 20°C, whereas the pickling solution, if a 1 per cent, acid solution is used, has to be kept at 40°C. On the other hand, hides which have been treated by the lye process are apparently unsuitable for stock tanning with metallic acids are used to neutralise the lye with which the material is impregnated. The lye process is, as far as at present developed, quite unsuitable for use in separate disinfecting stations, unless these can be established adjacent to the tannery.

If used in the tannery itself the lye process could be carried through as a special process in the same way as the pickling process. Experiments conducted in Germany have shown that ox-hides treated by the lye process can without difficulty at once undergo the further processes necessary to make them into hard leathers. The hides are placed straight in the lye solution, then softened, and sent on for further operations. Whether ox-hides so treated could be worked up into grades of leather other than hard leathers, and what influence the lye process has on hides and skins of other animals when it is conducted as a separate process previous to the softening, or what ultimate effect it has on the quality of the leather, has not yet been established by any practical experiments.

In fact, the lye process, if used as a separate process and not as part of the actual tanning process, is likely to be much less useful than the pickling process. Its advantage as against the pickling process is that it can actually replace liming and softening. This is of particular importance, for if hides have to be softened before they are disinfected there is the danger that the workers who place them in the softening bath or lift them out again may be exposed to infection, and that the water from the softening bath when leaving the factory as wash water may carry with it anthrax spores and infect the public water supply.

In many cases it ought to be possible to omit any special softening processes for hides and skins, and to place them straight into the lye solution. It may already be taken as proved that sheep and calf skins which have not been dried hard, and which are to be worked up into bark-tanned leather, can be subjected to the lye process without previous preparation and remain uninjured even if they have not previously been softened. Probably the same is true of a great many other hides and skins. In cases where a special softening process is absolutely necessary previously to the lye process, unnecessary contact with hides and skins and also avoidance of the infection of waste water may be prevented by carrying through the lye process in the softening pits themselves. This is done by keeping the softening solution in the pits and using it for the lye process. After the softening pro-

1 See also enquiries on disinfection of anthrax-infected hides by means of soda lye made by Dr Ottolech, in 1892.
cess has been finished the necessary quantities of soda, common salt, and an excess of hydrochloric acid are added; the soda and lime combine to form soda lye and carbonate of lime. The carbonate is precipitated and thereby carried off with it the impurities held suspended in the softening bath; when the sediment has settled the softened hides are placed in the lye bath.

The lye process has an advantage over the pickling process in that, in general, it is simpler and that no special acid-resistant baths or vats are necessary. Further, it can apparently, as has already been stated, replace the softening and liming processes. It therefore offers very considerable advantages in the case of smaller establishments; but even in the case of larger tanyards it might be preferable to combine disinfecting operations with one of the usual tanning processes and to avoid the buying of special plant.

More than one method, therefore, for disinfecting hides is known. There should not then be any reason for hesitation in prescribing statutory regulations on the subject. But as statistics show that only foreign skins constitute a real danger (90-95 per cent. of anthrax infections must be attributed to foreign hides and 5-10 per cent. at the most, but probably fewer in reality, to native hides), obligatory disinfection of native hides need not be insisted on. Moreover, disinfection of native hides and skins would be extremely difficult to carry out and most costly; to supervise it would be almost impossible.

Further disinfection of all imported hides and skins would be useless in the case of those coming from countries where anthrax is known to be non-existent or extremely rare, and in which, moreover, regulations are in force forbidding the flaying or use for any purpose whatever of the carcases of animals which have died of anthrax. This restriction would limit still further the gravity of the suggested step which would only be enforced against countries where anthrax is admittedly prevalent. It might theoretically be an ideal system to make an examination of every single parcel imported from abroad in order to disinfect those which were proved to contain anthrax spores. Such an undertaking would only be possible if a process were known to prove the existence of anthrax spores with rapidity and certainty. At present no such process is known.

It would be necessary to carry out a very large number of bacteriological experiments in order to test each parcel and such experiments would take at least several days. Apart from the great expense involved there would be great inconvenience from the commercial point of view and from that of the employer. Unless, therefore, a process is found which permits of the rapid and cheap testing for anthrax spores, the idea of carrying out a preliminary examination must be abandoned. Further if the circumstances should suffice to confine disinfection to those hides and skins which come from countries where stock is admittedly infected with anthrax. It is obvious that it would be both practicable and desirable to draw up regulations on an international basis and to secure their adoption in that way.

The final question which must be considered is whether disinfection should take place in special establishments set up at the principal ports of import or at the principal industrial centres, or whether it should take place in the tanyards themselves. There are undoubted advantages attaching to disinfection in special establishments. On the other hand, this is apt to be very expensive and an enormous hindrance to legitimate commerce, as is obvious. However great the advantages of disinfection in special establishments may be from the sanitary point of view, they are counterbalanced by its economic disadvantages as compared with disinfection in the tanyard itself.

The International Commission for the Study of Questions concerning the Preservation and Disinfection of Hides and Skins, which was nominated after the Conference held in Brussels in 1908, recommended the Seymour-Jones method to the attention of the authorities of the different Governments on condition that it should be put into practice at the ports of exportation and that the skins should be despatched wet in a condition of complete salting (Garçon, 1912).

In Germany the Minister of Commerce and in Prussia the Minister of Public Health recommended (1923) the process with hydrochloric acid and common salt (Schattenfroh), and urged factory inspectors and managers of factories to experiment with this method or with the soda lye method, especially where foreign hides were dealt with.

In some cases disinfection may have to be ordered. The German Federal Health Office is ready to give information to interested parties as to the best way in which to apply the method.

A Mixed Committee, comprising representatives of the Committees of Hygiene of the League of Nations and of the International Labour Office, has been nominated to study the problem of the disinfection of hides and skins. After having made experiments in the tanneries of France, Belgium and Great Britain, thank to the kind assistance of manufacturers, in testing principally the soda lye method, the Committee is

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1 While awaiting an effective method of disinfection Erban (1926) suggests using the method employing precipitins proposed by Ascoli for detecting skins contaminated with anthrax. To a clear aqueous extract of small pieces of skin there is added, rhus serum: out of 120 suspected hides Ascoli had a positive reaction for 115, out of 66 healthy skins no reaction.
about to experiment with alkaline sulphides. The long researches undertaken, which are both difficult and expensive, have not yet reached a stage at which conclusions can be drawn.

In Great Britain the British Leather Manufacturers' Research Association is devoting its attention directly to this problem and is organising a whole series of experiments.

In 1930 a detailed report was submitted to the Association by the secretary.

While the experts of the Mixed Committee of the League of Nations and the International Labour Office (Ottolenghi and Casaburi) are engaged in studying the resistance of the anthrax spores to solutions of alkaline sulphide and other substances capable of increasing its disinfecting power, in Germany research is being made into the possibility of disinfecting the skins with various products such as "Tetralol", "Sulfoliquid D", "Tetralol", "Bromtetrrolal", "Tetraloresorcin", etc. (Pohl, 1928).

A point of the first importance in these efforts against anthrax is assuredly the disinfection of the water after softening. The Advisory Committee on Industrial Hygiene of the International Labour Office, which studied this question in 1923, adopted the following resolution:

The Committee, fully recognising the difficulties of the problem, increased as they are by the present economic conditions, and having regard to these difficulties, considers that the only practical recommendation it can make at the present moment with regard to the waste water in which hides and skins have been softened, is that the sediment should be allowed to settle, reserving for the moment only the question of the disinfection of the sediment as well as that of the sterilisation of the waste water by treating the liquid at a suitable temperature so as to transform the spores into bacillus.

Furthermore, the Committee is of opinion that it is impossible, in view of the present industrial conditions, to complete the process, as otherwise would be highly desirable, by filtering, after the sediment has been allowed to settle, the waste water in which hides and skins have been softened.

It is thought that a filtration over sand, or at least a complete decantation of the effluent and its disinfection, after it has once undergone filtration, by means of chlorine or other suitable means approved by the competent authority would, as a consequence, diminish by 80 per cent. the danger of contamination and break down the vicious circle constituted by anthrax in the tannery and animal anthrax.

Legislation

The employment of women is prohibited in France in warehouses for skins and refuse from abattoirs, as well as in the dressing and unhairting of hides; in Argentina in the manufacture of varnished (patent) leather and in tanneries where they might be exposed to the dusts produced by the tanning processes.

Boys under fifteen years of age are excluded from the leather industry in Poland; in Italy (tanning, fulling, liming, where dust is liberated); in Estonia (in the varnishing, finishing, and manufacture of leather); under sixteen years in the province of Quebec (dressing and lustering); in Spain (degreasing of skins by means of hydrocarbons and other solvents; from rooms in which dusts are generated); in Belgium (varnished and lacquered (patent) leather factories), from Morocco leather preparation (where injurious smells are emitted: from knackers' yards or tanning); Greece (tanyards); young persons under eighteen years of age (dehairing, lustering and dressing of skins where dust is given off); female young persons under eighteen years of age in the province of Quebec (in the dyehouse, dressing and lustering of skins) and in Greece (tanyards); and under twenty-one years of age in Spain, Belgium, Italy, etc. (as in the case of boys). In Finland children are excluded from salting skins, and from four establishments where poisonous substances are used.

Young persons under sixteen are excluded from work on polishing machines in tanneries and leather factories in the States of Wisconsin, Arizona, Missouri, and Massachusetts.

Special rules for the hides and skins industry have been enacted in Prussia: Order of 17 April 1907 relating to skin diseases due to chrome; in Austria: Order of 1 August 1923, No. 558, as to the steps to be taken to protect the workmen against the risk of anthrax (paragraph C, sections 13-20, refers to the measures relating to premises where non-disinfected animal matters are stored or manipulated); in Great Britain: Regulations of 29 December 1921 for the protection of workmen against anthrax from dry and salted hides and skins imported from Africa and Asia; Welfare Order of 32 March 1922 relative to the protection of workmen in chrome tanning by the two-bath process and in job dyeing; in Russia: Order of 17 May 1922 on the installation and maintenance of the clothing industry (beating leather); Order of 28 September 1922 on furs and sheepskins (soaking, bathing, fleshing, dyeing, fulling, etc.); Order of 1922 as to the discharge and purification of effluent waters from leather factories; Order of 30 June 1922 on the installation and maintenance of tanneries; Circular of 8 May 1924 on the prevention of anthrax, with appendices containing instructions as to how to disinfect infected hides; in
MEXICO (Jalisco): Decree No. 2366 dated 13 August 1923, section 317. In Finland a Resolution dated 17 May 1927 sets out the safety measures to be observed in the saddlery, morocco leather and boot industry. In Lithuania, an Instruction of 5 September 1927 has reference to the skins industry. The German Professional Association for the Hides and Skins Industry published, as long ago as October 1910 very detailed instructions as to warehousing, manipulation and treatment of raw sheep and goat skins as well as foreign skins.

The "Syndicat général des cuirs et peaux" of France has circulated widely amongst those interested a small illustrated leaflet of seven pages relative to the diagnosis and the therapeutical treatment of malignant pustule (anthrax). The leaflet is edited by Abt and Perrin.

The Netherlands Factory Act requires the compulsory notification of cases of arsenical affections of the skin and eczemas in the hides and skins industry, as well as of inflammation of the tendons and subcutaneous cellular tissue occurring in persons engaged in stretching skins.

Anthrax contracted from hides and skins comes under the Workmen's Compensation Act in Austria, Canada, Great Britain, Japan, India, Queensland, Victoria, Western Australia, and in the States of Minnesota, Ohio and New York. In other countries it is specifically mentioned or is treated as an accident, as well as in those countries which have ratified the Geneva Convention of 1925 regarding compensation for industrial diseases.

In Japan persons suffering from erysipelas, plague, and smallpox in the hides and skins industry receive compensation.

(See also the articles "Occupational Diseases: Compensation", "Anthrax", "Horsehair, Bristles and Hair", and "Fur Trade").

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Fig. 178 was made from a photograph kindly supplied by the Factory Inspection Department in Belgium.

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HomeWork


Homework certainly constitutes one of the most serious and difficult problems of social economy and social hygiene. It is for this reason that, especially in the last few decades, a lively interest has been taken in the problem by experts and Government authorities, etc., as may be seen from the numerous publications and national and international congresses and exhibitions, as well as from various private and official enquiries, and the legislation devoted to the subject in many countries (Austria, Belgium, Germany, Great Britain, France, Italy, Norway, United States, etc.). The problem has become still more urgent by reason of the fact that numerous war invalids and disabled workers have, in all countries, taken upon work in their homes.

That the work in question has everywhere aroused such active interest is explained by the fact that it is the source of a series of evils designated by the expression "sweating system", which covers unduly low wages, a quality of work inferior to that effected in factories, unduly long working hours, night work,
over-working of women and children, bad conditions of environment, health risks for the workers and also for the consumers.

It is true that a series of laws and regulations assuring economic and hygienic protection for factory workers have been enforced, but only a very limited number of legislative codes have made provision for homeworkers.

If an attempt is made to define "homework" it is at once seen that it is impossible to provide a definition likely to meet with unanimous approval.

From the economic point of view, there may be distinguished 'traditional', popular, homework strictly related to the local produce — in general, it is a question of a small employer or artisan working for customers who know him and are attached to him — and home expert the exclusion of the homeworker whose activity is undertaken by his own account as small manufacture. Work. It must be confessed that the limits are not always very clear between these two groups of workers. In any case, they are both equally exposed to the same risks.

For legislative purposes there is, therefore, considered as "homework" all work executed with a view to gain in a room having, at the same time, another use bedroom, dining room, kitchen, without distinction being made as to whether it is the employer who possesses the premises or not, or at times, if work executed in a workshop constituting an integral part of the house, whether the employer is the proprietor or not, or, finally, all work executed by a wage-earner in a workroom not comprising a

work properly so-called, created by modern capitalism — here it is a question, on the other hand, of a wage-earner not in direct contact with the consumer. Such a distinction, however, is not admissible from a legal point of view. Today, these two forms of homework may often exist under the present capitalist organisation, but the type of work undertaken by private customers is becoming more and more rare, since homeworkers engaged in this way work rather for export, that is to say, on behalf of a middleman.

From a health and hygienic point of view, this distinction has to value, for the definition "homeworker" means a worker who works for an industrial undertaking, and implies for the hygiene part of his house, but for which he is obliged to pay rent, heating charges, etc.

In Germany, these are used chiefly in this connection the expressions "workers in domestic factories and workshops", "Hausgewerbetreiber", and "homeworkers" "Hausarbeiter". In the law relative thereto, use has been made, since 1911, of the expression "Hausarbeiter", which, however, is little used. Demarcation between the first of these formal expressions is not very definite. The "worker in domestic factories and workshops" is an intermediary form between the employer and the worker. He sometimes employs a few workers, but retains, in relation to the individual who passes him orders, the character of a wage-earner. In certain cases he himself provides the

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FIG. 178.
raw material and sells the products of his labour at his own expense. By "homeworkers" there is meant, in general, persons who, without outside assistance and under circumstances of complete economic dependence, work for a given employer. The term "Hausarbeiter" is none other than a synonym for "homeworker". The Hausarbeiter does not employ outside assistance, but works alone, or merely assisted by members of his family.

In all countries the number of "homeworkers" working on behalf of a middleman is very high. It is, however, very difficult to provide figures, since values available from the various enquiries are not quite comparable, such enquiries not being, in general, of recent date, and not applying to similar categories of work. It is, however, certain that amongst these workers, women and children form a high percentage, and that the work executed is of very varied nature (clothing, underclothes, textiles, ironmongery, fur work, rope-making, millinery, making of straw goods, artificial flowers, sweet-making, toy-making, etc.). It may be said that homework comprises a great variety of industries which demand, besides unskilled workers, some very highly specialised and skilled workers.

Causes of Injury

In enumerating the causes of injury due to homework, mention will here be restricted to sources of risk of a sanitary and hygienic character.

In general, homework is effected by persons for whom it represents a supplementary source of income. It is, however, equally engaged in in convents, reformatories, prisons, etc., with the result that the labour supply is greatly superior to the demand, whence lowering of wages favoured by competition and rendered worse by the exaggerated percentage of profits which goes to the middleman.

The result of insufficient wages, at times aggravated by the effects of the "truck system", is revealed, amongst other effects, by exhaustion due to physical overstraining and under-nourishment. Such conditions imply for women a source of still graver injury of a moral order (prostitution), and of a eugenic order as regards children (degeneration).

For the hygiene expert, injury due to excessively long working hours is of the greatest importance; in fact, whilst the working day is, in general, reduced to eight hours in the factories, for the homeworker this limit represents a minimum, mostly exceeded to a large extent, together with reduction of intermediary rest spells.

Without legal control, without protection against injury due to fatigue, homework is generally effected under bad environmental conditions. It is, in fact, carried out for the most part in premises not specially intended for the purpose, often in a bedroom containing several beds, or, again, in a kitchen. At times, even, the same room may serve the triple use of bedroom, kitchen and workroom. Under other circumstances, the premises in question may serve uniquely as a workroom, but are over-populated with workers who are obliged to work or rest in vitiated and, at times, dust-laden air. Such defective conditions are often still further aggravated by smells and fumes of cooking, which mingle with the atmosphere when windows are kept closed in cold weather.

The resulting injuries are more frequent and more serious when the rooms in question are badly ventilated or open into a courtyard. How often has it not been remarked that the worker is obliged to work on the doorstep of the building in order to enjoy fresh air and natural light?

Work prolonged throughout the evening by inadequate artificial light and, during winter, in rooms heated by stoves giving off toxic products (carbon monoxide) is likewise a source of injury. All enquiries made up to the present have invariably drawn attention to this insufficiency of accommodation, and Ranelletti, in his enquiry in Rome, has been able to assemble very enlightening data in regard to this subject.

None of the legislative measures issued relative to the work of women and children in factories is applicable to homework, which thus is free from a majority of restrictions (record of work, supervision of primary instruction, necessity of medical examination on admission to work, etc.). Similarly, night work, which is forbidden for women, of whatever age they may be, is very frequent among homeworkers. The Sunday rest is no more observed than the daily rest spells. The woman engaged in homework does not enjoy rest either after or before childbirth, as provided by legislation for the factory worker. All enquiries report abuse, particularly in regard to children employed before school age.

In Belgium there have been found cases of children of five employed in turning, and elsewhere children of three to four engaged in fixing buttons on cards. Where the children are obliged to go to school, they are made to work between school hours and even during the evenings. There has also
been reported the presence of the aged amongst homeworkers. Thus, in the manufacture of wreaths of artificial flowers in Germany and in lace-manufacture in Belgium, there have been found engaged persons of seventy, and even over eighty, years of age.

Sources of health risk for the workers as well as the consumer are numerous. Without further insisting on the causes already referred to (in brief, low wages, excessive work, night work, bad environmental conditions, etc., abuse in regard to work of women and children), and which certainly cannot fail to exert a pernicious influence on the health of those workers, attention must once again be drawn to the fact of the making military furnishings. From the age of ten, this young girl worked with her mother from 7 o'clock in the morning till midnight. Exhausted and anaemic, she fell a victim to pulmonary tuberculosis, which carried her off at the age of sixteen, ten days after the photograph was taken.

Fig. 177 shows a bedroom serving as workroom for three persons.

There must not be overlooked the danger represented by other infectious and contagious diseases, such as, for example, diphtheria, scarlet fever, typhoid fever, etc. In certain industries, besides infections it is necessary to recall the danger of poisoning of occupational origin, a risk which is diminished general organic resistance, involving predisposition to infectious diseases and, more especially, to pulmonary tuberculosis. Homework represents an important factor in the development of this disease, and it is hardly necessary to insist on the frequency of its incidence amongst homeworkers: tailors, dressmakers, embroiderers, ironers, seamstresses, etc. The enquiry made by Ranelletti in Rome has proved that exhaustion due to excessive work may involve predisposition to pulmonary tuberculosis.

Fig. 176 shows a young woman worker of sixteen years of age lying a victim to pulmonary tuberculosis beside her mother, a woman worker employed in greater than in the case of the corresponding industries carried out under factory conditions. The poisonous product most utilised is naturally lead: porcelain industry, painting of fancy articles in fashion, etc. The lead risk threatens not only the worker who handles the toxic product, but also all the members of his family living in the same room. Thus, for example, a woman who had lived and slept for twenty years in the same room in which members of her family manufactured pottery, showed a clinical picture of lead poisoning, without ever having been engaged in glazing of the pottery (Ferrannini). Research effected by samples taken from the clay floor-
ing, from the furniture, linen and clothing, have shown a high lead content, which explains the extensively disseminated poisoning amongst members of the same family, and sometimes even attacking domestic animals. The manufacture of artificial flowers frequently effected in the workers' homes under the most unfavourable hygienic conditions may present a risk of lead poisoning due to the absolute lack of means of personal protection and especially to the habit of taking meals in the room in which the work is carried on. It should, however, be noted that an enquiry effected in Germany by a technical committee received no complaints relative to this work. The same risk of poisoning has been noted amongst workers manipulating yellow amber on a lead support; amongst setters of pearls, who often remove with their tongues the excess of the mastic which connects the pearl to the gold and is composed of lead and gum arabic; amongst polishers of plastic objects, who finish the stones on a lead grinding wheel; amongst dressmakers and embroiderers, who handle silk and materials rendered heavy by the application of lead preparations; amongst lace-ironers, who powder the lace with white lead to obtain a fine white colour; and amongst decorators, who handle varnish and other mixtures with a lead basis, etc.

Poisoning by mercury may affect homeworkers manipulating raw materials for hat-making (carrotted skins and pelts prepared by carrotting, which, in certain countries, is still done in the worker's home). The danger of poisoning by mercury has been reported as occurring amongst thermometer makers and amongst workers engaged in colouring in vermilion in their homes. Various enquiries and congresses have insisted especially on the danger of tuberculosis and other infectious diseases, citing a series of instances which prove that the objects manufactured in the workers' homes by tubercular subjects may act as carriers of germs and disseminate infections. Various enquiries and congresses have insisted especially on the danger of tuberculosis and other infectious diseases, citing a series of instances which prove that the objects manufactured in the workers' homes by tubercular subjects may act as carriers of germs and disseminate infections. Various enquiries and congresses have insisted especially on the danger of tuberculosis and other infectious diseases, citing a series of instances which prove that the objects manufactured in the workers' homes by tubercular subjects may act as carriers of germs and disseminate infections.

The question regarded from the point of view of the consumers is no less serious. It suffices to say that, for some time back, fires had not been reported as occurring in the homes of workers engaged on this work, as a result of the precautions taken.

The danger is naturally more serious where it is a case of work connected with alimentary products or tobacco, toys, etc.

**LEGISLATION**

It has been proposed to suppress entirely homework, since it is "insufficient for supporting life and all too sufficient as a cause of death". In order to heal, however, it is necessary to treat, and not to kill. Homework cannot, therefore, be enjoined, since it provides the mother of a family with a means of supplementing the income of the other members (mostly of a single member) which is insufficient to the family's
needs, and because it offers the opportunity of working to all those who would be incapacitated, on account of physique, or other defects, of entering a factory.

It must be confessed that, in the first case, its suppression would increase misery or change the mother to go and work in a factory, thus destroying the happy life which is the kernel of society. In the second case, the suppression of homework would increase the number of infants individuals remaining a burden to society.

It is therefore most urgent and it may also be said, most essential, to maintain homework by regulating it, and so protecting those engaged in it.

The first efforts in this direction have been due to private initiative. Attempts have been made to institute trade unions for an association to regulate homework, to institute associations for consumers with a view to buying products manufactured at the home without the control of industry. These means have not, however, been productive of practical results, or have even caused more serious evil wages than those which were intended to suppress.

It has been equally perceived that the best way to achieve are, on the one hand, the raising of wages, and on the other, improvement of hygiene and sanitary conditions. It is for this reason that legislative interference has become necessary, with a view to applying these measures, the basis of legislation of this nature has already been established by various meetings of the International Association for Labor Legislation, between 1896 and 1906, Genoa, Berlin, London, and by the International Congresses on Homework, 1906 and following. These measures may be summarised as follows:

1. In the interest of the workers:
   a) fixing of minimum wages by mixed committees of employers and employees;
   b) obligation on the part of the employers to maintain a list of homeworkers and to keep registers for each of these workers;
   c) extension to homework of fundamental hygiene and social legis-
at present, but also whilst it is running its course. That is to say, that in agreement with the factory inspectors, the health authorities should report each case of illness to the employers, who should, where necessary, assure disinfection of the material handled during the period of infection before such material is returned to them, or should even proceed to suspension of work. In any case, homework should be prohibited where it is a question of raw materials which it is impossible to return to them, or should even proceed in the case of material intended for the food industry.

Towards the end of the nineteenth century, legislative intervention occurred not only in regard to wage regulation, but also in regard to health and hygienic conditions, as well as organisation of the workers. The pioneers in this sphere were the United States and Australia, the latter in regard to wage regulation, and the former in regard to protection of health, but more particularly in favour of the consumers.

In Great Britain, the movement for the protection of homeworkers resulted in the appointment, in 1888-1889, of a Committee (Select Committee of the House of Lords on the Sweating System) which was only able to obtain an extension of the health measures applicable to factories. The Royal Commission of 1891-1893 extended to these workers the legal protection of children, as well as the hygiene measures, but it was only in 1906, when the first exhibition of homework was held in Berlin, that the movement underwent rapid development. The same lines have been followed in other countries, especially in those in which there have been held congresses and exhibitions of homework (Zurich, Brussels, Frankfurt, Paris, Amsterdam, etc.).

Legislation is essentially directed to two points: fixing of a minimum wage and protection of the health of homeworkers.

The existing laws may be grouped as follows:

General laws, containing provisions applicable to homework:
Belgium, Bulgaria, Denmark, Italy, Netherlands, Poland, Portugal, Sweden, Switzerland, Yugoslavia.

Laws or parts of laws concerning suppression or regulation of homework:
Ohio, by the Acts of 1896 and 1926 (3), prohibits homework, whilst it is prohibited or subjected to regulation in the United States (Connecticut, 1899-1919; Indiana, 1899-1926; Maryland, 1896-1924; Massachusetts, 1891-1921; Michigan, 1901-1915; Missouri, 1899-1919; New Jersey, 1893-1917; New York, 1892-1923; Pennsylvania, 1895-1915-1922; Wisconsin, 1901-1925, etc.).

Laws or parts of laws relative to homework, and especially to the minimum wage:
Australia, 1900-1922; Austria, 1918; Canada, 1911-1917; Spain, 1926.

Special legislation:
Argentina (1918), in which the law chiefly deals with the minimum wage; Czechoslovakia, 1919; France, 1915; Germany, 1911-1923, Great Britain, 1902-1911-1918; Norway, 1918-1923; Switzerland, 1919 and Bill of 1923.

The legislation covers, however, hours of work, age of admission for women and children, and night work. In certain countries, social insurance laws relative to sickness, old age and unemployment cover also homeworkers.

mention is here restricted to some details in regard to hygiene and safety. In general, it is a question of measures of hygiene relative to the premises in which the work is effected. Thus, for example, the United States demand clean, well-ventilated rooms, heated in the cold season, and free from vermin, etc.; cessation of work in the case of contagious disease in the house; minimum cubic space per worker employed. All distribution of homework is subject to a special permit. The State of New York forbids the use of certain premises in dwelling houses (cellars, subterranean premises, etc.). In several countries there is also prohibited the employment of women and children on work likely to harm their morals.

Legislation in Europe is less strict. The Norwegian Act of 1918-1923 (section 54) is the most advanced in regard to the hygienic prescriptions demanded.

The British Factory and Workshops Act, in its sections dealing with homework (sections 107-115), confers on district councils very important powers of controlling the conditions under which certain classes of work are done in the homes of the workers (section 108). These powers conferred on the local authorities refer, in particular, to regulation or, under the following conditions, to prohibition of homework, in the case of conditions injurious to the health of the workers employed (overcrowding, lack of ventilation etc.), or in the case of risk of contagion from infectious diseases.

By virtue of the Homework Order of 10 April 1911, local authorities may exercise powers in respect of certain classes of homework specified by orders of the Secretary of State and classified according to the two causes of ill-health above referred to.

The Order also requires that employers should provide the local authority with complete lists of the persons employed by them on homework. It only applies in part and to domestic factories and workshops. For details, see Memorandum as to the Duties of Local Authorities under the Factory and Workshop Acts, pp. 10-15, published by the Home Office.

The German Act authorises the Federal Minister of Labour to prohibit entirely, or to provide measures of protection relative to, branches of homework.
involving a health risk. The Minister of Labour has so far issued detailed Orders covering two branches of this work (tobacco, celluloid), and has prohibited several others (rag-sorting, manufacture of powder for fireworks, gluing of water proofs). Similar powers to those accorded the Minister have been granted to local police authorities and to factory inspection officials for isolated work shops. They are permitted to issue provisions relative to the protection of the health, and to regulate the work of children and young persons.

The French Act (section 2 of Book II) is only applicable in the case of workers other than the family of the proprietor being engaged on homework, when dangerous or unhealthy work is effected, or if power machinery is used.

The Austrian Act (section 15) is valid only in the case of unhealthy work, children being subject to section 74 of the Labour Code.

In Czecho slovakia, the legislation is similar to the preceding: the employment of children, as well as the use of certain products in special circumstances, is prohibited.

In South America, legislation in Argentina only takes effect where it is a question of unhealthy trades, or when a steam boiler is situated in the workroom (section 5).

In Italy, section 21 of the Labour Charter provides for the benefit and protection of the industrial collective contract being extended to homeworkers. Definite regulations will be issued to ensure hygiene and control of homework.

It is not possible to analyse further here the very abundant and detailed legislation which exists on the subject. It will suffice to state that, from the health point of view, American legislation, for instance, has achieved good results. The number of workrooms conforming to the minima demanded by the Health Service are becoming more numerous. It may be stated, in brief, that the present laws are insufficient, rather than ineffective. It is therefore necessary to improve, complete and correct those which already exist, with a view to rendering them more effective. Inspection of homework is, indeed, an ungrateful, delicate task, and one which it is still, at the present time, easy to elude. Yet it can, and ought, to be achieved.

International legislation is essential in view of economic competition. The role played by production from homework in national production (exportation) was discussed at the Congresses held in Basle (1904), Zurich (1906), etc., and the problem of prohibition of night work in 1910, etc.

The International Labour Conference in 1921-1923 examined the question of minimum wage regulation in the worst paid trades (see documents published by the International Labour Office).

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— Per la difesa contro la tubercolosi in rapporto al lavoro a domicilio. Rome, 1912.

Cf. especially the reports of the International Labour Congresses on Homework (Berlin, Zurich, Brussels, etc.); the publications of the National Associations members of the International Association on Homework; the National Enquiries into Homework (Belgium, France, Germany, United States, etc.); the reports of the German Committee presented to the Exhibition on Homework, etc.

Cf. also the publications of the International Labour Office in regard to the fixing of a minimum wage (1928).

The illustrations (figs. 176, 177 and 178) used in this article have been kindly supplied by the author.

Prof. A. Ranelliti
(Rome).

Horn Articles (Manufacture of)


Horn used industrially is obtained from horns of animals and to some slight extent also from the hoofs of certain domestic animals. True horny matter is really a modified form of the epidermic tissue and consists of keratin and of albuminoid matter containing sulphur. It is a semi-transparent elastic substance, heavier than water, varying in colour (white, yellowish, grey, black, etc.), possessing the property important from a technical point of view — of being easily softened by heat (100 °C. in boiling water), becoming pliable and malleable and lending itself to welding by compression.

The kinds of horn used are chiefly those of oxen, cows and buffaloes. The horn used is rarely native, since these are often too short or subject to deformation by use of the yoke. Commercial horn is obtained chiefly from Hungary, Galicia, European Turkey, South America, India, and China. The more compact the product is, the greater is its commercial value; it has generally a smooth surface, being rugged only at the root. Various forms and dimensions exist, according to the breed of animals, some being more or less twisted, and almost round in cross-section. These horns are partly or totally hollow inside.

According to the purpose for which they are intended, there may be distinguished various classes of horn, such as horn for manure (manufacture of manure, animal
HORN ARTICLES

The chief processes in the preparation of horn are extraction of the horn by immersion in water, removal of the points (the points of horn are utilised for the manufacture of very small objects), polishing (scraping and flattening of the horn, which is pressed against a cylindrical tray provided with knives, and revolving at great speed), cutting and sawing. During the latter operations, waste from the solid and hollow parts is recovered for the manufacture of small objects (handles of sticks and of knives, buttons, etc.).

Combs made of horn are cut on a ribbon screw. Under the influence of pressure and heat, the horn sheet takes on an even thinness and is ready for perforating. The horn is scratched and rendered thinner on the toothed side, then passed to a comb saw, which forms the teeth by means of a rapidly revolving circular saw. The article is then finished on an emery polishing wheel. The teeth are sharpened by passing over a scraper, then rendered smooth on another machine, and subsequently polished with a leather polisher and pumice-stone, and finally with chamois leather and tripoli powder.

Imitation whalebones are generally made of buffalo horn. After cutting, soaking and polishing, the pieces of horn are again soaked before passing to the following operations: flattening out under a press, cutting, treating with pumice-stone in a grinding mill, polishing with tripoli powder and chamois leather, colouring, chiefly with linseed oil for light-coloured whalebone; drying is effected in a barrel with sawdust, followed by polishing with a buffer to remove oil and dust.

Hoofs are mostly used for the manufacture of buttons. After being sawed into sheets, the latter are heated, scraped, reheated in water, and cut out into buttons by stamping in a hydraulic press; piercing of the holes and polishing follows.

Manufacture of hairpins comprises somewhat similar processes: sawing, turning, bending, sharpening, rubbing and polishing.

Industrial Processes

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Manufacture of hairpins comprises somewhat similar processes: sawing, turning, bending, sharpening, rubbing and polishing.

Horn is rendered opaque by treatment with minium, potassium, hydrochloric acid, or by immersion in acetate of lead, then in hydrochloric acid, which causes the formation on the surface of the horn of chloride of lead, which renders it quite white. Prepared in this way, it is ready for further treatment by any kind of aniline colouring agent. Black shades are still obtained by the use of nitrate of sulphur, or in bringing the horn to the boil in acetate of lead; red shades by the application of gold chloride, and brown shades by nitrate of mercury. There may also be used lime "saleratus" (impure bicarbonate of potassium), or even acid colouring agents, which dye the horn directly (Indian yellow, wool blue, alizarine grey). The operation is effected by means of an acetic solution of the colouring agent to which has been added a little sulphate of soda, the whole being carried gradually to the boiling point. Washing in water follows, and drying by exposure to air, bleaching being effected by the solution of acetate of lead. Washing in a bath of peroxide of hydrogen to which there has been added sulphuric acid, followed by rinsing in pure water, drying in a stove, and finally a further application of the dye with the object of improving the appearance of the product.

Sources of Risk

Apart from the odours given off, the sources of occupational risk comprise septic wounds, effects of fumes, liquids and dusts. Danger from septic wounds is chiefly confined to the operations of cutting, sawing and polishing the crude horn, which gives rise to the projection of very sharp particles liable to injure the worker. It is as a result of pricking with sharp points or splinters of horn that workers manufacturing horn objects become inoculated with dangerous germs.

Horn dust is composed of particles with very acute angles, which render this dust more dangerous than bone dust. There should similarly be mentioned the injurious action which may possibly be exerted by the various products utilised in the course of the different processes (colouring agents and mordants with a lead, mercury or other toxic basis, etc.).

Pathology

Septic wounds may lead to inflammation following the normal course, but more often they give rise to specified disease forms from which the animals may have suffered. The most
important of these is anthrax. Buffalo horn is particularly dangerous in this respect, since in the case of animals affected with anthrax, the horns may be the seat of abscesses covered with a crust which may be opened during the operation of polishing the horn, with the result that the septic liquid which they contain spurts up in the worker's face. The dried horns are said to be free from danger, but they are liable to become dangerous from the fact that they are submitted to soaking during three weeks.

The dust generated is likely to set up forms of irritation on the ocular mucous membrane (blepharitis, conjunctivitis), or on the respiratory mucous membrane (bronchitis). Furthermore, according to Hirt, animal dust is more apt to give rise to pre-disposition to tuberculosis than vegetable dust. He quotes in fact the following figures relative to the incidence of this disease:

<table>
<thead>
<tr>
<th>Per thousand</th>
<th>U.S.</th>
<th>England</th>
<th>France</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industries without a dust risk</td>
<td>11.1</td>
<td>13.3</td>
<td>20.8</td>
</tr>
<tr>
<td>Industries in which the worker is exposed to vegetable dusts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industries in which the worker is exposed to animal dusts</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

**STATISTICS**

Straus has reported a certain number of cases of malignant pustule amongst workers engaged on flattening imitation whalebones. From 1886 to 1889 there were reported in the Department of the Seine seven cases of anthrax among workers manipulating horn. Cases of anthrax notified often are connected with those due to handling of bones (see article "Bones Industry").

**HYGIENE**

In the majority of countries the manufacture of horn is included in the schedule of dangerous and unhealthy trades, and subject on that account to a certain number of specified measures: removal of factories in which maceration is carried out, from the neighbourhood of dwellings; provision of impermeable flooring for the workrooms; lime washing of walls, unless these have been coated with oil paint in order that they may be washed down with a plentiful supply of water; strict cleanliness of the workrooms and regular washing with chlorinated water or water to which formalin has been added; effective ventilation of the storerooms containing the raw material. Special measures are required with regard to disposal of the waste water containing material which putrefies readily. Such waste water must be filtered before being allowed to escape into the drains and deodorised by means of calcium carbide. Special measures are equally required in regard to the emanation of disagreeable odours, such, for instance, as the provision above the maceration vats of exhaust heads supplied with a very strong draught.

As a protection against infectious diseases, and particularly against anthrax, apart from ordinary prophylactic measures it is essential to provide for the disinfection of raw materials, as has already been done by legislative regulations in various countries and as has been recommended on several occasions by the Advisory Committee on Anthrax, the Correspondence Committee on Industrial Hygiene of the International Labour Office, and the International Labour Conference (see article "Bones Industry"). Such disinfection can be assured by long-continued boiling at a high temperature or by the action of formaldehyde fumes. It is also necessary to draw up appropriate regulations for the protection of transport workers; provision of special working clothes; strict cleanliness; and the provision of first-aid treatment for transport of raw materials in closed receptacles (sacks, sealed trucks).

In regard to dust, suitable measures should be taken to diminish production thereof (work done wet wherever that is possible) or, on the other hand every effort should be made to catch the dust at its source and prevent its dissemination in the atmosphere, particularly during the operations of polishing, which are the most harmful in this respect.

The requisite precautions are also required in regard to the products used in the course of manufacture and should be adopted in accordance with the risk offered by each of these.

**LEGISLATION**

Legislation is similar to that already described in relation to the manipulation of bones (see article "Bones Industry"). Compulsory obligation to import horns which have not been cleaned in special receptacles set apart for the purpose; disinfection on importation of bones which have not been cleaned is compulsory in Australia, Canada and the United States. Compulsory disinfection before any industrial manipulation is required in Austria. In France such disinfection is merely recommended. Legislation in regard to notification and compensation is similar to that issued in regard to bones (see article "Bones Industry").

Prof. A. Kober (Washington).
HORSEHAIR, BRISTLES, AND HAIR


RAW MATERIALS

The term "horsehair" includes the mane- and tail-hair from cattle and horses, but does not include short hair from cattle, nor hair from goats or camels.

Horsehair comes chiefly from China, Russia, Italy, the Netherlands, and South America.

Bristles are got from hogs and, more rarely, from wild boars. They come from France, Germany, Austria, Poland, Russia, and China.

Hair is got principally from rabbits, hares (see article "Haircutting"), goats, camels, and, more rarely, from martens and skunks.

Horsehair, bristles, and hair are largely used for making brushes, shaving brushes and paint brushes.

Fibres of vegetable origin are also used in this industry, e.g. tampico, bassine, bahia, pizavaf, coco, broomcorn (see article "Brooms"). Horsehair is used in the furnishing trade, but foreign vegetable fibres, resembling horsehair, and obtained by separating the inferior part of a certain variety of palm (Attalea funifera) which is found in Brazil, Ceylon and Western Africa, are frequently used as a substitute. Whalebone cut in sufficiently fine threads is also used as a substitute. Artificial horse-hair is prepared by passing paste through fine holes by means of a screw plate.

Attention is now called to the study of the occupational dangers originating from horsehair and bristles in the course of industrial operations during the manufacture of brushes.

INDUSTRIAL OPERATIONS

Work on Horsehair

On arrival at the factory horsehair is cleaned and disinfected in order to destroy anthrax spores which can be carried by it (see below, section on Hygiene).

First, the bundles of horsehair are opened on sorting tables, so that the horsehair may be classed according to its industrial qualities, with regard to colour, shade, thickness, and length.

Next, the process of "combing" arranges the fibres, which are held in the workman's hand, parallel, the comb being fixed to the edge of the bench or of the sorting table. This process eliminates fibres which are too short, as well as waste and impurities which escaped detection at the sorting.

There follows boiling, which frees the fibres from fat and, by means of the heat, prevents their distortion. Flexibility and the necessary straightness of the horsehair are thus assured. The horsehair is fixed by a ligature around a wooden peg and then soaked for some hours in cold water. Finally it is gently boiled for at least three hours.

The raw materials destined for making ordinary brushes are not subjected to the above process.

The dripping horsehair is now taken to a drying chamber where a fire is often arranged under the floor; there the bundles of horsehair are placed on trellises arranged one above the other in layers.

Next comes dyeting, generally in black, which is done by soaking the horsehair, after removing the wooden peg, in a solution of logwood or aniline dye.

After drying and a little combing of the dyed products, the fibres are cut to the desired length. Then follows "mixing", which is done by spreading out on a table the different fibres, such as horsehair alone, horsehair and bristles, horsehair and vegetable fibres. When mixing is completed, bundling is proceeded with, that is to say, gathering the mixed products into bundles which are then weighed, combed and tied up.

Work on Bristles

Bristles, like horsehair, arrive at the factory generally prepared and cut. They should be subjected to the following operations: disinfection, drying, sorting, combing and boiling, for which last they are wrapped round with hemp or jute. As the fibres are not so long, there is no question of carrotting. Those bristles which are to be bleached are subjected to the action of sulphur fumes, or of other decolorisers such as peroxide of hydrogen. Made up into small packets in a linen cloth which is tied securely by a string or a piece of wire, the bristles are then put into an oven, where, as they dry, they regain their stiffness.

For paint brushes and other fine brushes, bristles only are used. For coarser brushes the bristles are mixed with horsehair.

Vegetable fibres go through numerous processes. Thus, for example, pizava and tampico must be combed with a vertical iron comb, very much like the comb used for hemp. Tufts
which have been combed are cut by guillotine-shears or a carving knife.

The pieces of wood, backs or mounts for brushes, may be made of poplar, birch, beech, or oak, or from foreign woods. Horn, bone, ivory, tortoise-shell, metals, and celluloid are also used as brush backs. This is why a modern brush factory has to employ a large number of such workmen as carpenters, cabinet-makers, polishers and drillers. As soon as the backs or mounts are ready, holes are drilled, into which little tufts of bristles are to be inserted. If the mount is of bone or horn, it is subjected to degreasing in boiling water, after which the pieces of bone are polished in a barrel containing a mixture of Spanish white and grease.

The bristles are fixed in the holes with strong glue or tar, applied to the under surface of the piece of material used for the back of the brush; this surface is then sealed with a mixture containing tar, hide, holes, threads and the layer of glue. For mounting paint brushes and brushes for polishing, the quantity of fibres necessary is weighed and put into a holder, which fixes the bunches of bristles in the perforations by means of a gas flame or an electric heater. Lead poisoning may also arise from the lead slab on which the horsehair is cut.

As regards dust, it must be remembered that there is an enormous quantity generated during such operations as opening out, sorting and combing, and that it is excessively fine; debris, dried blood, mud and dirt are also present and are deposited on the uncovered parts of the skin and easily penetrate into the respiratory passages, the nasal fossae and ears.

It must also be borne in mind that fumes are given off by the solvents of cements and by melted pitch; and likewise that there is the risk from fire and from explosions of dust.

The preparation of hog bristles is carried out with or without fermentation. The first method gives off a nauseating stench and raises dust during the beating and sorting of the bristles. The waste water is extremely liable to putrefaction because it contains large quantities of organic materials in solution and in suspension. Stoving may be a cause of danger from fire.

Sources of Danger

In the horsehair, hair and bristle trade the most important dangers arise from dust, anthrax, and, more rarely, from glands. The dangers of less importance are cases of dermatitis caused by the use of artificial cement with a tar basis; of shellac, dissolved in methyl alcohol, used to fix the hairs in fine brushes; of cement with a base of colophane or resin; of pitch or a mixture containing tar, heated by means of a gas flame or an electric heater. Lead poisoning may also arise from the lead slab on which the horsehair is cut.

As regards dust, it must be remembered that there is an enormous quantity generated during such operations as opening out, sorting and combing, and that it is excessively fine; debris, dried blood, mud and dirt are also present and are deposited on the uncovered parts of the skin and easily penetrate into the respiratory passages, the nasal fossae and ears.

It must also be borne in mind that fumes are given off by the solvents of cements and by melted pitch; and likewise that there is the risk from fire and from explosions of dust.

Statistics

According to a Belgian enquiry the proportion of workers under twenty years is quite high. The age of entering the trade had been very early, almost half having commenced before the age of twelve (247 boys under twelve years for brush factories against 334 in tanneries and 59 in the places where hairs are cut). On the other hand, late entries into brush works are rare. The proportion of persons having a short period of service is lower than the average for men and higher than the average for women. On the contrary, men with twenty-five years’ service, and even more than forty, are not rare in brush making.

The Belgian enquiry showed that the general state of health of the male personnel was satisfactory and that, as regards the female personnel, the proportion of persons in good health was slightly above the average.
As a matter of fact, out of 596 workmen, 89.05 per cent. were in a good state of health and 10.95 in a medium state; out of 152 women, 83.98 per cent. were in a good state and 16.02 in a medium state. The division of the personnel according to their state of health and the nature of the work gave the following rates:

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th></th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Good</td>
<td>Medium</td>
<td>Good</td>
</tr>
<tr>
<td>Preparation and moun-</td>
<td>89.49</td>
<td>10.58</td>
<td>83.98</td>
</tr>
<tr>
<td>ting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finishing</td>
<td>91.67</td>
<td>8.33</td>
<td>91.67</td>
</tr>
<tr>
<td>All work</td>
<td>87.05</td>
<td>12.95</td>
<td>87.05</td>
</tr>
<tr>
<td>Accessory</td>
<td>90.00</td>
<td>10.00</td>
<td>90.00</td>
</tr>
<tr>
<td>operations</td>
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</tbody>
</table>

Radiographic examination revealed a high percentage of pneumoconiosis.

The results of an enquiry made among employees in one of the 15 factories of Kharkov, working in the bristle industry, have been presented by Chworostanky (1925). From figures given in reference to 100 workmen and shown by cases of sickness and by age groups, the following have been extracted: pulmonary tuberculosis, 6.9 per cent. (men), 6.7 (women); pneumonia, 3.6 (men), 3.1 (women); acute diseases of the upper respiratory passages, 7.3 (men), 5.0 (women); pneumonia, 3.6 (men), 3.1 (women); acute diseases of the digestive organs, 7.6 (men), 4.4 (women). A total showed 275 cases of sickness for the 100 men, with 2,349 days of illness, and 180 cases for the 67 women, with 2,261 days of illness.

The author considers that the high morbidity in this industry may be explained by the fact that the work does not require great physical strength, and that, in consequence, the personnel includes persons of weak constitution and even those suffering from chronic diseases.

An enquiry by Schergin in 1924, dealt with 293 workmen employed at four factories in the town of Weliky Ustjug, working and on bristles. Nearly all these workmen were employed part of the year on agricultural work. Most of them commenced their work in the industry between ten and fourteen years of age: 76.5 per cent. of the workmen examined were sick; the morbidity was higher among men than women, and very young, and these also suffered from deformity of the thorax in a proportion of 7.5 per cent.

The injurious influence of dust is clearly shown by the following statistics: respiratory diseases, 41.6 per cent. of patients; skin diseases, 15.7; disorders of the digestion, 8.8; conjunctivitis, 6.5; diseases of the heart and anaemia, 5.7; hernia, 2.3. Tuberculosis is distributed by age group as follows: 2.6 per 100 cases for age group 18-27; 12.5 for the group 28-37; 8.6 for the group 38-47; 14 for the group 48-57.

As regards anthrax caused by handling horsehair and bristles, statistical returns are as follows:

**Austria.** — From 1897 to 1907, 50 cases of anthrax occurred in a single horsehair weaving mill. From 1907 to 1908 various cases were reported from a factory making false beards with horsehair. In 1909 hog bristles caused 10 cases of anthrax. In 1910 again 5 cases were reported; in 1913, 9 cases; and prior to 1918, 3 cases. In 1922, 2 cases occurred, one in a brush factory and the other in a mill for weaving horsehair. In 1924 a fatal case was reported in a brush factory, and 3 cases, one of which was fatal, in some horsehair weaving mills.

**Belgium.** From 1899 to 1920, 55 cases of industrial anthrax were reported to the medical inspection department: 35...
cases occurred among brush makers and 4 among horsehair weavers. The small number of factories for curled horsehair seemed for a long time not to be affected. However, one case was reported in 1903; 2 a few months before the war (1914), and another case occurred in 1919.

France. — Thirty-four cases of anthrax occurred in the horsehair and hair industry from 1910 to 1922; they are classified as follows according to the industrial operations during which the contamination occurred: preparation and weaving, 27; brushmaking, 2; mattress making, 4; yarn making, 1.

In 1923, 79 cases of anthrax, 9 of which were fatal, were noted. Among these, 5 occurred in mattress work, 1 in horsehair weaving, 2 in manipulating horsehair and curled horsehair.

Germany. — From 1910 to 1921 this industry claimed 113 cases of anthrax out of a total of 1,458 for all industries, or 7.7 per 100 cases notified. Among these, 5 occurred in mattress work, 1 in horsehair weaving, 2 in manipulating horsehair and curled horsehair.

In 1923, 79 cases of anthrax, 9 of which were fatal, were noted. Among these, 5 occurred in mattress work, 1 in horsehair weaving, 2 in manipulating horsehair and curled horsehair.

In 1924, the cases numbered 23, out of a total of 218, or 10.6 per cent. The proportion of fatal cases was then 20.4 per 100 cases occurring in the industry of horsehair, hair and bristles. If the occupational grouping be studied, it is found that 70 cases, of which 10 were fatal, occurred among horsehair weavers; 31, of which 10 were fatal, in the manufacture of brushes and paint brushes; 5, of which 2 were fatal, among persons employed in the horsehair and hair trade; and 7, of which 1 was fatal, among various workers, such as brush-sellers and hairdressers.

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very dangerous, but can be easily cured by early intervention (use of serum, cauterisation, etc.)

Netherlands. — The figures regarding this industry are incomplete. In 1912, 16 cases were reported among brush makers and in 1922 two cases. (See the report of the medical inspector of factories for 1922.)

United States. — Nichols (Massachusetts) reported 26 cases in three years in one horsehair factory. The Massachusetts State Board of Health in 1908 reported on 4 cases of anthrax which occurred during the period 1901-1908. Following the introduction into the factories of disinfection for horsehair, cases of anthrax disappeared.

In the State of New York 7 cases of anthrax, 2 of which were fatal, were reported during the period 1912-1920 in brush factories, against a total of 84 cases, 16 of which were fatal, for all industries.

PATHOLOGY

Cutaneous eruptions, erythema, furunculosis and anthrax are fairly common. A special dermatitis, characterised by a bright redness of the fingers and palms as well as acute hyperhydrosis (Hejermans), is seen chiefly among workmen who clean horsehair and bristles with hot and cold water and comb them when wet. Dust, which collects under the nails, is a mixture of dried blood, hairs, and epidermis. The hyperhydrosis of the hands of brush makers is caused by the use of hypochlorites.

Sometimes callosities are met with on the fingers, and contractures of the right middle and ring fingers, caused by the use of scissors for trimming. Cramps and neuroses of the muscles of the fingers occur in the case of workmen employed in binding the hair round the wooden pegs.

The use of wire is the cause of rhagades situated on the left thumb, although workmen protect the place by a piece of leather.

Dust sets up inflammation of the respiratory organs, of the external ear, and blepharitis. Some authors claim that perforating rhinitis occurs (Hejermans). It is probable that respiratory catarrhs prepare the ground for the development of a tuberculosis infection. Among workmen who escape tuberculosis, konicotic changes of the lung are found (Scheinin).

Fumes from pitch and tar, used as cement, have, according to some authors, an injurious effect on the kidneys. And it is generally accepted that headache and irritation of the mucous membranes of the eyes and throat occur.

Among brush makers an irregular development of the body and an insufficient chest measurement are noticed. Various authors have found that apprentices are rapidly fatigued, and exhibit a febrile reaction accompanied by shivering, pains in the limbs and cough. But these symptoms improve and pass off gradually as the workers become accustomed to the work.

As regards anthrax, see article "Anthrax".

HYGIENE

Hygiene measures are the same as those laid down for any unhealthy industry. Roofs, walls and ceilings should be rendered impermeable by oil paint, so that they can be washed with a hose pipe, or be lime-washed, which requires to be renewed yearly. The general ventilation of workshops must be adequate; local ventilation is required for all the apparatus, in order to carry away the dust given off in the course of industrial operations, by directing it to furnaces or to a moist chamber. Diurnal periodical cleansing of the workshops and of work benches is necessary. The operations of selecting, sorting and combing, and in fact all operations of a dusty nature, should be carried out in separate places by means of apparatus provided with efficient dust exhaust. Workmen affected with bronchitis, tuberculosis, or predisposed to respiratory diseases should be excluded.

Workshops should be illuminated by lights which are well protected, or placed outside behind glass frames.

All necessary measures must be taken to prevent any danger of fire when gas engines or petrol motors are used to drive the machinery. Furnaces should be placed away from and outside the workshops. Motors or machines for heating or carding must be sufficiently far from the party-walls so that vibrations do not annoy the neighbours.

As regards the preparation of hog bristles, in addition to what has just been said, it is necessary to cover with a coat of plaster or oil paint all exposed woodwork to prevent it becoming impregnated with smells; all beating of bristles should be done mechanically and in closed apparatus; dust produced in this operation should be burnt in a furnace; macerating vats should be supplied with covers and placed under hoods directing the gases into a factory chimney, which must be of adequate height; similarly hoods should be placed above all healing vats; water from maceration should be received into
waterproof tanks, where it should be first decanted and then purified before being discharged outside; the tanks should be frequently cleaned out, and the debris and mud which have collected removed to fields in closed barrels; the workplaces should be frequently washed with plenty of chlorinated or formalised water.

The employer should supply the workmen with working clothes and head dresses, which he ought to keep in good repair. Workers should take a hot bath at least twice a week. Cloakrooms and dining-rooms should be provided.

Homework on horsehair and hair which has not been disinfected should be forbidden. Danger from fumes of pitch and tar is slight. The chief risk is due to the temperature. It should be sufficient to provide the receptacles with exhaust hoods. Any danger of lead poisoning is minimal.

On the other hand, the risk of anthrax infection is more serious. However, the means for combating this risk are now clearly defined and various Governments have for some time past laid down special regulations.

In Germany instructions regarding compulsory disinfection of horsehair and bristles of foreign origin are laid down by the Ordinance of 22 October 1902; they were published in 1926 by the Factory Inspection Department in a revised form after consultation with the Federal Hygiene Office.

For disinfection by means of steam under pressure, only apparatus working with steam circulating under a plus pressure of 0.15 atm., into which it is possible to introduce a bundle of horsehair with a surface of 90 x 90 cm. and 100 to 120 cm. high, without actually dividing it as it is loosened, is approved. The steam should enter at the top and pass out by a pipe fixed at the lower part. The apparatus should be fitted with a safety valve and a manometer under control graduated in twenty-seconds of an atmosphere. It is strongly recommended that an automatic registering apparatus should be made use of for the pressure. The exit steam pipe should be fitted with a thermometer placed in a conspicuous position.

The apparatus should be installed in a compartment separating two workplaces, one intended for articles that have not been disinfected and the other for articles after disinfection, with no direct communication between the two places. But when a single workman carries out the work on both sides of the compartment, a small room fitted
with baths and douches should be placed between.

All disinfecting apparatus should be inspected every year. The person in charge of disinfection should be instructed by a course of public service disinfection. All those who suffer from wounds on the neck, face or hands should be excluded from handling non-disinfected goods or from charging the apparatus.

All straps or metal bands encircling the bundles must be opened during disinfection; similarly, packing materials or paper must be spread open. Any material over the dimensions given above should be divided up. If, after the operation, the goods seem clothes and sponges should be put into the apparatus with the parcels of hairs.

If possible the interior should be heated for 20-30 minutes so as to raise the temperature to 60° C. Steam is then passed into the apparatus. From the time the manometer shows a plus pressure of 0.15 atm. and the thermometer a temperature of 104°-105° C., the disinfection should last half an hour. During this time it is absolutely necessary not to increase the pressure above 0.20 atm. and the temperature above 107° C., or to allow the pressure to fall below 0.10 atm. or the temperature below 103° C. After the apparatus is opened, heat should, if possible, be maintained for 20 minutes at 60° C.

When disinfection is being effected by boiling water the apparatus should have a capacity twice the volume of the hairs or bristles contained in each batch. It should be, if possible, of greater height than width, and in any case of equal height. A cylinder completely hemispherical gives better results than a quadrangular drum. The upper part should be covered with a layer of non-conducting material. The apparatus should be placed in its own compartment and fitted with lids opening on each side of the wall and having efficient fastenings and a safety valve.

Fig. 180. — Autoclave for disinfection of horsehair. (Italian factory, C. Pacchetti, Pavia.)
An arrangement should be provided which renders it impossible to open the lid of one side unless the lid on the other side is closed, and also which prevents the lid of one side from being opened from the other side. The receptacle should be furnished with a perforated plate, or a carefully adjusted grill, placed as to prevent the goods from being raised above the level of the water.

Adequate arrangements should ensure a regular supply of water, kept at a constant level. The goods to be disinfected should be put in by means of forks.

The receptacle should be half filled; then filled with water up to the top; next having taken the precautions laid down for disinfection under pressure.

The goods should be immediately taken to the drying chamber. All contact with non-disinfected goods must be avoided.

A method has also been suggested consisting of disinfection for a quarter of an hour by means of a 2 per cent solution of potassium permanganate, followed by decolorisation by a 3-4 per cent solution of sulphuric acid.

A disinfectant which seems to combine the essential conditions is chloramine, which can be used at 65°C in a 1.5 per cent solution for six hours. Experiments made in hair-weaving factories, using spores of Bac. mesentericus,

the perforated plate is placed in a position which should force the upper part of the goods half way down the receptacle.

The disinfection should last at least two hours after the first definite ebullition. The workman should not leave the place the whole time, and should watch from the non-disinfected side the level of the water and that of the goods.

At the end of two hours, the water is run off, the emptying valve is closed and clean water run in, which is then drained off. The lid on the non-disinfected side is then fastened; and that on the disinfected side is opened, after which are quite as resistant as those of anthrax, as indicator, prove that resistance to steam lasts only 3 to 7 minutes. Laboratory experiments have shown that spores of Bac. mesentericus are killed in eight hours with a solution of chloramine at 18°C to 21°C; at 37°C, three hours are enough with a 2 per cent solution; at 55°C, fifteen minutes suffice even with a 0.5 per cent solution.

In factory trials the hair was not damaged, and white hair was readily bleached. Hot chloramine solution makes an excellent cleansing medium, and would greatly help after cleansing processes. A preliminary bath with
soft soap enables the duration of disinfection at a temperature of 60° C. to be reduced to one hour. But practice has shown that this diminution in the period of disinfection with the preliminary bath is of very little advantage, and that it is much more convenient to adopt a single operation, even if it is a little longer, such operation permitting either of disinfection, or of the cleaning necessary for dissolving the dirt.

In Belgium the disinfection of hair for brushes does not offer any serious difficulty. The steam method is as a matter of fact applicable and efficacious for all hair which is not of a white colour. Still, this disinfection should be carried out under conditions which assure its judicious use and efficiency. The degree of pressure, the temperature, the presence of moisture for consideration. Steam circulating or not, are all factors that have for a long time past been made the object of thorough study on the part of the factory medical inspection department. The disinfection of hairs for brushes is carried out under conditions which areobtained by stoving at 103° C. for one hour, or by keeping for two hours in boiling water, or bleaching.

In Great Britain investigations by a Government Committee for the disinfection of horsehair have made it clear that the method employed for disinfecting wool could be satisfactorily applied to hair from the manes and tails of horses. According to the Home Office Consultative Committee on Anthrax, varieties of hair coming from Russia, Siberia and China must be subjected to disinfection. For hair from tails certain modifications are, however, necessary, but simply on account of the exigencies of industrial operations and not because the process of disinfection is insufficient. As regards semi-prepared horsehair and shaving brushes coming from China, in view of the impossibility of disinfecting them in a satisfactory manner, the Committee suggested in 1921 the total prohibition of the importation of any manufactured or semi-manufactured hair, as well as any goods made entirely or partially of horsehair or goat-hair coming from abroad; and also the establishment, in countries exporting these goods, of disinfecting stations under the control of a local authority charged with disinfecting the raw hairs before any industrial operation.

This question, which is of the utmost practical importance on account of the numerous cases of anthrax caused by shaving brushes, has been the object of much study in the United States and Japan.

It has also been dealt with by a temporary Committee on Anthrax appointed by the International Labour Conference in 1921. As a matter of fact the Committee in its report presented to the Conference in 1923 was of opinion that a proposal should be made to the
The Governing Body of the International Labour Office to put on the agenda of a future Session of the Conference a proposal on the following lines: all hair used in brush making and in the furniture trade shall be disinfected before any industrial manipulation.

The Committee considered that hog bristles should be exempted from compulsory disinfection.

In conclusion it should be added that Brodsky in 1924 after a searching enquiry in certain States of the U.S.S.R. was of opinion that not only horsehair, but also pig bristles are the cause of anthrax infection among workers in the industries in question and that it is necessary in consequence to submit these also to compulsory disinfection.

Finally, the necessity of prohibiting the manipulation of unwashed horsehair from suspected sources must be kept in view; likewise that of separately warehousing for washed hair from those for unwashed hair; it is also essential that store-rooms for unwashed hair should be disinfected periodically; that the personnel, especially that employed in washing, combing and sorting, should be instructed in regard to the risks to which it is exposed; and, lastly, that medical supervision should be established over the state of health of the personnel with suspension of all those who suffer from lesions of the skin of the hands, neck and face.

It is essential for every factory where the personnel is exposed to risk of anthrax infection to organize a first-aid service, so as to permit of ready intervention in any case of suspected anthrax with injections of anti-anthrax serum.

LEGISLATION

The employment of young persons under sixteen years is prohibited: in Germany in horsehair and brush factories at disinfection work and at manipulations which precede disinfection; in certain States of the United States of America at sorting, combing, and weaving; in the State of New Jersey in any industry where either vegetable or animal dust is set free in an injurious quantity. Employment of boys under fifteen years is prohibited in the operations of beating, combing and cleaning hair, whether animal or vegetable, in Italy and Japan when there is any dust given off: the employment of boys under sixteen years in Belgium in the workshops for curled animal hair, when dust is given off freely, as well as in the preparation of hog bristles by any process of fermentation, cleaning and preparing bristles and carding short bristles; and of boys under eighteen years in France in the same operations. In Belgium, in the brush factories children under fourteen years are excluded from the workshops where the preparation and combing of plucked and bristles is carried on. In the Netherlands, section 41 of the Factory Act (Royal Decree of 10 August 1920) lays down the conditions under which young persons and women may be admitted to the work of sorting and handling raw wool or other hair of animal origin, as well as in brush-making shops where the air may be fouled by dust. In the following countries, Belgium, Italy, Spain, and Japan, women under twenty-one years are excluded from the above-mentioned operations.

Special legislation for the horsehair and hair industry, including compulsory disinfection of hair and bristles of foreign origin, has been passed in Germany (Ordinance of 22 October 1902, revised in 1926), in Belgium (Royal Decree of 20 August 1908), in France (Decree of 1 October 1913), in Great Britain (Order of 1907), in Hungary (Ordinance of 1905), in Russia (compulsory Order of 20 February 1922).

In Germany the Circular of the Chancellor of the Reich, dated 22 October 1902, deals with the erection and inspection of horsehair weaving mills, factories for horsehair, brushes and paint brushes. In an appendix are given instructions for disinfection, as regards the installation and control of apparatus and processes of disinfection, either by autoclave or by boiling.

In Prussia an Ordinance of the Minister of Commerce and Labour, dated 18 December 1909, deals with the employment of young persons in operations bringing them in contact with vegetable fibres, hair of animal origin, offal and rags. Another Ordinance, of 20 December 1910, deals with the protection of workmen against the infection of anthrax.

In Japan a Regulation passed in 1925 prescribes the disinfection of imported horsehair. The disinfection is to be done at the port of unloading where the formaldehyde process in an autoclave is used.

For the regulation of factories working on horsehair, bristles and hair, see, as regards the prevention of anthrax infection, the article "Hides and Skins," for the same measures apply also to factories working on horsehair, bristles and hair. The compulsory Russian Order of 20 February 1922 deals with the erection and supervision of factories dealing with bristles, horsehair and brushes. In Great Britain the Act of 22 July 1919, dealing with the prevention of anthrax, with regard to the supervision of importation of infected goods, or goods likely to be infected by anthrax spores, provides for the disinfection of the said raw materials.

Pulmonary affections in workmen employed on hair, as well as dermatitis and eczema occurring among workmen in brush factories, are compulsorily notifiable.
in the Netherlands, Erysipelas, anthrax, plague, and small pox caused by work on animal hair are compulsorily compensated in Japan. Anthrax caused by horsehair, hair, and hog bristles is compensated in the following countries: Austria, Great Britain, Canada, India, Queensland, Victoria, Central and Western Australia, in the States of Minnesota, Ohio, New York and in those countries which have ratified the Geneva Convention of 1925 relative to compensation for occupational diseases. In several countries anthrax is compensated "by definition" or as "an industrial accident".

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Hotels and Restaurants


The hotel industry includes several categories of occupation which may expose the personnel to dangers to health. Gast and Plötzsch mention, among others, as potential hazards: excessive and irregular hours of work; work in places crowded by customers and in a bad atmosphere (tobacco smoke, etc.; the greatest strain of work during the evening and night hours, thus reducing the time for recuperative sleep; working either standing or moving about; bad housing; the opportunities for consumption of alcoholic drink.

Statistics seem to show that this last cause is of secondary importance, as it is customary today for the employee to pay for what he consumes (beintker).

Statistics

According to some old statistics of the Leipzig Sickness Fund, which deal with the period 1887-1904, the sickness rate for the personnel of the hotel industry appears as much higher than the average rate of sickness for all other occupations. The best figures included 17,073 male workers, including waiters, barmen and refreshment-room keepers, aged from fifteen to fifty-four years, out of a total of 92,674 male wage earners belonging to all occupations (Plötzsch). The lost working days were caused, particularly amongst barmen between fifteen and thirty-four years, by venereal disease, acute and chronic rheumatism, laryngitis and haemoptysis; and for the group from thirty-five to fifty-four years, by hepatic affections, cystitis, chronic rheumatism, gout, cancer, gastric ulcer, and ulcers on the legs.

In the case of cooks the position was still worse: for during one year, taking 1,817 insured persons, gout was responsible for 259 days of sickness. The number of working days lost on account of sickness was assessed at 30 per person by the Association of Hotel and Restaurant Employees of Geneva, and at 25.1 by the Leipzig Sickness Fund, which gave 21.4 as the average for all occupations.

Some other statistics, somewhat out of date, i.e. for the years 1903-1905, concerning hotel-keepers in the Berlin Sickness Fund, relating to an annual average of 18,133 members, of whom 10,203 were women, gave a total of 6,762 cases of illness, of whom 4,098 were women. Sickness benefit was paid to each sick person for an average of 28.9 days (31.8 for men and 30.9 for women). Similar figures have been given by another association of hotel-keepers in the same town.

Analysis of these 6,762 cases shows that the most important diseases were, in order of frequency: disorders of the digestive organs, respiratory diseases, diseases of the locomotor apparatus, venereal diseases, anaemia, nervous diseases, and diseases of the skin.

From the point of view of age, persons engaged in the hotel industry are mainly between fourteen and forty; that is the period at which the death rate is lowest and the capacity for work reaches its maximum. Above forty years of age the number of persons employed diminishes, owing to the fact that, on the one hand, too high an age is incompatible with the
work demanded, and, on the other, that comparatively few persons remain in the industry beyond that age.

At any rate, according to the Association of Hotel and Restaurant Employees of Geneva, the average sickness rate calculated for the period 1903-1910 must be considered as very high, seeing that it may reach 10.2 per cent. under relatively favorable conditions. But in a large number of cases employees in this industry avoid absenting themselves as much as possible, for absence due to illness entails losing the daily gratuities which make up an important part of their wages (Beimker). Recent (1927) statistics of the Leipzig Local Sickness Fund show that the position of the auxiliary personnel, either male or female, are relatively better, although the rates are still higher than the average.

Among causes of death of secondary importance, the English figures show tuberculosis, respiratory diseases, pneumonia, cerebral haemorrhage and circulatory diseases.

For barmen the maximum mortality occurs between thirty-five and fifty-five years, with a comparative mortality figure of 1,955, which is only exceeded by four other occupational classes, all of which carry a high silica risk. The most common causes of death are cirrhosis of the liver, diseases of the digestive organs and the circulatory system, cancer, syphilis, chronic nephritis, cerebral haemorrhage, tuberculosis, respiratory diseases and suicide. Further, the mortality from accidents is also rather high.

In the case of waiters the mortality is high at all ages, and the comparative mortality figure is 1,323. In order of importance the diseases causing death in this class are cancer, syphilis, cirrhosis of the liver, diabetes, tuberculosis, diseases of the digestive and respiratory organs. The comparative mortality figure for cancer for this class is here found higher than for all other occupations.

When 178 occupations are classified according to the mortality shown by different diseases and the figure 1 is given to the occupation with the least mortality and the figure 178 to that in which the mortality is highest, it is evident that persons aged from twenty to sixty-five years employed in the alcoholic drink trade occupy an unfavourable position.

This fact is due to the diminution already mentioned in the number of wage earners of over forty years in the different categories of the hotel industry.

It is worth noting that out of 40.6 cases of death from infectious diseases, 32 were due to tuberculosis. If this disease is included in the group of respiratory diseases a death rate of 45.5 per cent. for this group of diseases is obtained. The high mortality from diseases of the heart has been ascribed to chronic alcoholism. Among such varied occupational categories as chambermaids, valets, and the auxiliary personnel, the highest mortality is met with among waiters: it represents almost 50 per cent. of the total mortality of the group mentioned above (Gast).

According to English mortality statistics for 1921-1923, the position of the hotel industry is as follows: for innkeepers the death rate increases after the age of twenty-five years and reaches a maximum between thirty-five and fifty-five years, at which age it exceeds by 100 per cent. the standard comparative mortality figure (C.M.F. taken as 1,000). Rates above this standard are found for almost all causes of death; they are particularly high for diabetes, disorders of the digestion, chronic nephritis, suicide and cirrhosis of the liver. The innkeeper is therefore particularly exposed to the evil consequences of abuse of food and drink, opportunities for which occur to him on occasions inherent to his occupation.

As regards the death rate of those working in the hotel industry, it is above the average total mortality for occupations. According to the Leipzig statistics, the most frequent causes of death for all age-groups were: cerebral haemorrhage and nephritis; tuberculosis (6.66 against 3.32 per thousand for all occupations); cancer (1.40 against 0.47); and hepatic diseases (0.70 against 0.18) (Ploetzsch).

In Berlin the average mortality has been placed at 7.16 per thousand (10.2 for men and 4.8 for women). The mortality diminishes rapidly after the fortieth year;

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<tr>
<th>Number of insured</th>
<th>Percentage of the total of insured</th>
<th>Number of cases of sickness</th>
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<th>Percentage of the total cases of sickness</th>
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English statistics show that out of 2,118 brewers, 5,457 cellarmen, and 66,362 persons employed in the hotel business, 15,660 barmen died during the period 1921-1923. For the standard group the comparative mortality figure was 1,017, whilst for the groups in question it reached 1,683.

PATHOLOGY

The relatively high rate of sickness which is met with among persons employed in the hotel industry is chiefly due to accidents, such as falls and burns, to a tendency to varicose veins and to the risk of aggravating flat feet and the condition of genu varum (Gast). In addition, venereal diseases occupy an important place in the statistics; this is explained by the kind of life which the wage earners in this industry sometimes lead and especially young girls, who, under some conditions, are exposed more than they would be elsewhere to dangers of a moral and physical kind. The effects of fatigue and strain may also be seen among these employees, especially during the “season”, when the night’s rest may not only be diminished or suppressed, but even poorly compensated by some hours of sleep during the day.

The German Society of Industrial Hygiene (Deutsche Gesellschaft für Gewerbehgiene) in November 1928 considered the question of diseases of cooks without coming to a definite conclusion. It was, however, proved that the working days lost by these persons are chiefly due to bad hygienic conditions of the workplaces, and notably to bad ventilation and exposure to draughts. On the other hand, working in heated and moist air constitutes another factor predisposing to various diseases. In modern establishments measures have been taken to suppress all these injurious causes.

For a long time it has been recognised that when cooks work in establishments the equipment of which is old or badly arranged, they are permanent-
to the bites of crabs (Gilchrist). Whitlows have also been noticed following abrasions by the kitchen knife or by splinters of wood; injuries of the thumb may occur, and sometimes even an accident caused by the mincing machine with amputation of the end of the thumb (Jerusalem). Among the various dermatoses properly so called, eczema and *lichen tropicus* should be mentioned. This last develops chiefly in the armpit and in the fold of the groin, on the genital organs, and on the thighs and abdomen. *Lupus erythematosus*, which is found among cooks, has been attributed to the injurious effect of successive heat and cold (Lassar).

Syphilitic infection of the mouth has been caused by the use of the same spoon for tasting (Julien, Rollet, Tschistiakoff). Cancer of the tongue and oesophagus is attributed to the action of heat from dishes tasted while very hot (Lévy).

In a number of cases a susceptibility to certain vegetables has been noticed, which explains the frequency of carrying plates on the right hand in a restaurant waiter, who, by dint of carrying plates on the right hand in the extended supine position, developed a cramp of the hand whenever he tried to carry a plate in this way (Runge, 1873).

**Hygiene**

Prophylaxis against the risks which may threaten the health of hotel personnel should first and foremost include measures of a social kind. Hours of work should be regulated, with abolition of overtime during the evening and night hours; by systematic organisation a proper distribution of rest intervals between busy spells should be established. Any tendency to the abuse of drinks, especially alcoholic ones, should be combated by adequate means, such as education. The personnel should be housed in accordance with the hygienic measures laid down for sleeping places and in particular for their ventilation (Gast). Defective cooking ranges should be replaced by more modern types which ensure an effective exhaust for the gases. Protection should be provided against the action of heat rays. Machinery should be used for washing plates and dishes. Apparatus for removing steam and vapours without creating draughts should be installed.

**Legislation**

Most Governments have laid down measures dealing with the employment of women and children in public-houses and shops where alcoholic drinks are sold, as well as measures dealing with the length of work for persons employed in the hotel industry.

In Germany the Act of 15 January 1920 concerning persons employed in inns and shops selling alcoholic drinks provides for the establishment of measures by provincial authorities for controlling admission to the service and the method of remuneration of female personnel.

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**House Porters**


Although no complete monograph exists relating to the living conditions and work of house porters, certain relative data referring especially to

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1 This article refers to hygienic conditions of Continental concierges, there being no corresponding category of workers in Great Britain.
their unsatisfactory housing conditions are to be found in medical literature.

Thus, for example, Passot, after visiting in 1851 the homes of house porters in Lyons, remarked on their extremely unsanitary condition. He drew attention on the same occasion to the frequent incidence of rheumatism amongst these workers and of scrofula amongst their children.

Fifty years later Lortet resumed the study of conditions in the same town by following, over a period of several years, the incidence of tuberculosis amongst house porters. The very high percentage for this disease was explained by the great number of houses without outside windows, by the permanent obscurity of such dwellings, and by overcrowding. Four-fifths of the 390 houses examined were declared uninhabitable, and Lortet arrived at the conclusion that out of 17,000 such houses in Lyons, 14,000 were uninhabitable and should be reported to the Health Office. On the basis of an average of three persons per dwelling house, Lortet deduced that about 50,000 individuals were fatally exposed to the risks of tuberculosis.

Amongst other studies of the kind may be recalled that of Friedel presented to the Second International Congress on Hygiene and Housing (Geneva, 1906), in which the harmful effect of these dwellings was attributed amongst other causes to the high carbon dioxide content of the air and the humidity of the walls.

This expert, as well as others, remarks that the situation of the dwelling houses in question, often in basements, is a cause of injury to health (effect of dust, noise, vibration, etc.).

The enquiry made by Kahn in Berlin in 1910, and Pergot and Bourelle in Paris (Geneva, 1906), by Fraenckel at Charlottenburg in 1912, all lead to the same conclusions. Fraenckel remarks on the fact that house porters are usually unflit for heavy work, and are on this account led to choose a light occupation, which is unfortunately likely to injure their already delicate health. The incidence of tuberculosis has on many occasions been related to overcrowding, want of sanitation in dwellings, and in particular to the type of housing provided for house porters.

In 1914 the Consiglio superiore del Lavoro in Italy, at the request of one of its members, passed a resolution that economic, hygienic and sanitary conditions affecting house porters should be inquired into. The Ministry of Labour requested the Technical Inspection Department to report on the economic conditions and the Medical Service on the hygienic and sanitary conditions. The enquiry covered about 2,400 house porters in ten towns, and as far as possible in good localities, consequently in those which probably represented the most favourable living conditions for house porters. An analysis of the data thus assembled showed that on an average 18 per cent. of the house porters were women (with a maximum of 44 per cent. in one town), that in general house porters took up the work in question at an advanced age, that sanitary conditions were usually good (61.5 per cent.) or average, (26.5 per cent.), and that naturally they were good in proportion to the class of house with which they were connected.

In 606 cases there occurred 14.8 per cent. of diseases of the locomotory system, 14.1 per cent. of diseases of nutrition, 15.8 per cent. of diseases of the respiratory system, and 11.7 per cent. of diseases of the circulation, etc. The number of persons living in one house was, in over 50 per cent. of the cases, two to three. It was not possible to assemble exact data relative to the diseases of members of the families of the house porters. The data regarding overcrowding of the houses were more accurate. In 25.6 per cent. of the cases the accommodation provided was adequate for the members of the family, in 18.4 per cent. only it was more than sufficient, with the result that in 55.9 per cent. the number of rooms was inferior to the number of persons occupying the dwelling. This proportion was naturally greater in the poorer quarters. Hygienic conditions were generally far from satisfactory. For details as to natural lighting, drinking water, etc., placed at the disposal of house porters, it is preferable to consult the report.

Quite recently (1927) in Paris attention was drawn to the unhealthiness of dwellings provided for house porters, even in the more modern and often the most luxurious buildings. Sanitary regulations are for the most part not applied, and infraction does not incur any punishment. The plans presented for inspection do not conform to the plans actually carried into effect, or are subsequently altered.

Regulations (dated 4 April 1925) regarding house porters and night watchmen are in force in the U.S.S.R.

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Hydrochloric Acid

(Muriatic Acid)


PROPERTIES

Hydrochloric acid (symbol HCl) is a colourless gas, with a sharp smell and acid taste, giving off dense and irritating white fumes, and having a specific gravity of 1.27. It liquefies easily; its boiling point is —83.7° C. at ordinary pressure and —10° C. at 40 atm. It melts at 111.3° C. It is very soluble in water; a litre of water dissolves 503 litres of gas at 0° C., 450 at 18° C. This solution constitutes the acid of commerce, which takes two forms: (1) yellow acid, the colour of which is due to impurities such as sulphurous and sulphuric acids, chloride, bromide, iodide, arsenic, alkaline chlorides and alkaline earths, iron salts, and organic substances; (2) pure acid, which is a colourless liquid. The density of these two kinds of acids depends on their concentration; an acid of 31° Be (that most generally used) has a specific gravity of 1.17 and contains about 33 per cent. of hydrochloric acid gas. The concentrated acid fuming in the air has a specific gravity of 1.19 and contains about 38.16 per cent. of hydrochloric acid. A weak acid with specific gravity of 1.07 and containing 15 per cent. of the gas is also used.

Although dry hydrochloric acid gas does not attack iron, its reaction with all the metals at temperatures more or less high, with the formation of chlorides and hydrogen. Mercury and silver, however, are not attacked. With metallic oxides, hydrochloric acid forms chlorides and water; it decomposes sulphides yielding hydrogen sulphide and displaces the acids of numerous salts: phosphates, carbonates, borates, silicates. Its characteristic reaction is a white precipitate of silver chloride with silver salts.

Hydrochloric acid gas combines with ammonia, forming white fumes of ammonium chloride. It can only be kept in glass receptacles with ground glass stoppers, or in stoneware vessels. Thus, basins of vitrified brocks are used, held by a special cement of sodium silicate and powdered asbestos.

INDUSTRIAL PROCESSES

These comprise (a) preparation, (b) condensation, (c) purification.

(a) Preparation

Preparation is carried out by the following processes:

(1) Muffle furnace process.—This is based on the reaction between sodium chloride and sulphuric acid, in accordance with the following equations:

(1) \( \text{H}_2\text{SO}_4 + \text{NaCl} = \text{SO}_3\text{NaH} + \text{HCl} \)
(2) \( \text{SO}_3\text{NaH} + \text{NaCl} = \text{SO}_3\text{Na}_2 + \text{HCl} \)

Hydrochloric acid is a by-product in the manufacture of soda by utilizing sodium sulphate (Leblanc process). For a long time it was regarded as a waste product.

The manufacture is carried out in a furnace consisting of two parts; a pan of lead or cast iron where reaction (1) is effected at about 100° C. and calcination in the muffle furnace to which the charge next passes. It is in the second part that reaction (2) is carried out at a temperature of about 650° C. In the first part of the furnace, acid sulphate of sodium is produced, which is converted into a neutral sulphate in the second. Hydrochloric acid yielded by these two reactions escapes along special pipes; that portion produced in the making of acid sulphate (reaction 1) is collected separately as it is the purer of the two.

The treatment of the mass in its passage from one part of the furnace to the other is done by hand, with the aid of rakes. The hydrochloric acid thus obtained contains sulphuric acid, ferric chloride and arsenical compounds.

Mechanical furnaces do away with hand labour, which is arduous, and as their action is more perfect the temperature can be lowered to 450°, and purer products are thus secured. Numerous models of such furnaces are made (furnaces of Pease, John and Walsh, MacTear, Larkin, Mannheim, Howard, Rhenania, Thelan and Wolf, etc.).

(2) Meyer process.—Bisulphate of soda, which is a residue in the manufacture of nitric acid, is used in this process according to equation (2). An intimate mixture of the bisulphate, finely powdered, and sea salt falls through a tower provided with plates in series, heated to 400-500° C. Mechanical arrangements cause the mixture to descend regularly in such a way that
the reaction is ended when the mixture arrives at the bottom. The gases do not contain iron or sulphuric acid and attain a strength of hydrochloric acid of almost 100 per cent. This process has been modified and perfected by Zahn (cornue de Zahn, the Zahn retort).

(3) Hargreaves and Robinson process. — In this process sulphuric acid is not used. The hydrochloric acid is produced in a mixture of steam and sulphurous acid gas to pass over an agglomeration of sea salt.

(4) Synthetic process. — This process, which is applied in America and in Italy, uses the chlorine and hydrogen formed in the course of the electrolytic manufacture of soda. Numerous processes exist which consist of burning chlorine in hydrogen (Volta, Roberts, Baumann). The danger of explosion which certain processes may present is avoided by the method proposed by H. and W. Pataky, who effected the synthesis by making the two gases pass through a column filled with wood charcoal.

(5) Preparation from chlorides as the starting point. — Hydrochloric acid is obtained plentifully from the decomposition of chloride of hydrated magnesium, which is obtained in large quantity from Stassfurt salts as a starting point. (Processes of Eschelmann, Weldon, Pechiney, Hepke.)

(b) Condensation

On leaving the sulphate (salt cake) furnace the gases (a mixture of hydrochloric acid, air and water vapour), which leave the pan at a temperature of nearly 180° C., and the muffle furnace at a temperature of nearly 300° C., are cooled by passage through an overhead system of earthenware pipes where any dust is also deposited. Use is often made of condensation in small towers, loosely packed, for cooling as well as for elimination of some of the sulphuric acid, which the gas may contain. The water does not circulate continuously in these, but is supplied in sufficient quantity to cool and moisten the packing so that the sulphuric acid is kept back and only a little hydrochloric acid is condensed there.

Condensation proper takes place either through a series of earthenware Wolfe bottles (bonbonnes) or in condensation towers, one metre in diameter, built of acid-resistant stoneware. Generally, the two systems are combined, the gas passing first through a tower, then through the bonbonne and finally through a terminal tower which retains the last traces of hydrochloric acid. The acid condensing in the first part of the system contains sulphuric acid, and is not used. This condensation furnishes a solution of hydrochloric acid equal to 21-22° Be containing from 30-33 per cent. of pure acid. After some time, a viscous mud forms in the towers obstructing the flow, and necessitating periodic cleaning of the towers.

(c) Purification

Of the gas. — Condensation succeeds in effecting a certain amount of purification by eliminating sulphuric acid and certain metallic salts. While sulphuric acid is sufficiently easily eliminated by means of barium chloride, the arsenic, on the other hand, is more difficult to get rid of. This is effected by means of iodides and hydriodic acid (Fischer process); by stannous chloride (by passage of the gas to a tower containing porous substances impregnated with this product), or oxides of vanadium (Harkort); by treatment with mineral oils (Mannheim process); by dichlorobenzol or carbon tetrachloride (Griesheim).

Of the solutions. — The sulphuric acid is precipitated by the addition, after slight dilution, of barium chloride. The arsenic is removed by flotation with mineral oils, after treatment with hydrogen sulphide, and by distillation. The addition of barium chloride precipitates at the same time sulphuric acid as barium sulphate, and the arsenic as sulphide.

The pure acid necessary for making sugar is prepared by rectifying the acid obtained by the above processes; after having previously removed the ferrous and ferric compounds, the hydrochloric acid is driven out of the solution by action of sulphuric acid, then condensed afresh in an absorption tower (processes of Deacon, Solvay, Rhenania, Haën, Scheuer, Tentelew).

TOXIC ACTION

Gaseous hydrochloric acid has an irritating and caustic action. Lehmann and Matt have shown that 0.16 mg. per litre has an irritating and very disagreeable action, that 0.5 mg. is not without danger, and that 1.6 mg. can only be borne for a few minutes. According to Ronzoni, 0.15 mg. administered for 30 days to animals is harmless to them. Acclimatisation to the gas has been little studied, but Lehmann does not doubt it.
According to this expert, man can bear a proportion of 0.01-0.02 per cent. of hydrochloric acid gas, but a stronger concentration produces the characteristic signs of poisoning. He reports however the case of a strong person who could not stand a proportion of 0.005 per cent. According to Lehmann, the air in factories ought not to contain more than 0.001 per cent.

Hydrochloric acid attacks the mucous membranes of the respiratory tract and eyes—the lesions are local without general symptoms of poisoning. The quantities absorbed (70 per cent. of the quantities inhaled) are not sufficient to set up an acid intoxication from absorption.

Hydrochloric acid in solution has a caustic and irritating action on the skin—the more readily exercised if there are small erosions. It is less dangerous than sulphuric acid because, when concentrated, it gives off pungent fumes which call the attention of the workers to its presence.

The seriousness of the accident depends upon the concentration of the liquid and the length of time it has been in contact with the skin or mucous membranes. Its corrosive action is less intensive than that of sulphuric acid.

In animals the following clinical signs are noted: redness of the conjunctivae, caustic effect on the mucous membrane, often developing into necrosis, dry or weeping; loss of the nasal mucous membrane; salivation; shortness of breath; pulmonary oedema, hyperaemia; in strong doses it attacks the cornea. As a sequela typical pneumonia has been observed.

Dangers

During the manufacture.—The workers in front of the sulphate furnaces are exposed to the inhalation of hydrochloric and sulphuric acid fumes, especially at the time of charging the furnaces or withdrawing the sulphate of soda. Further, risk of poisoning by carbon monoxide is run by the workers at the muffle furnaces. At the same time acute poisoning by hydrochloric acid gas rarely occurs, because the workers never breathe the acid fumes in very high concentration.

In the Hargreaves process there is risk of inhalation of sulphurous fumes. Further, cleaning the towers where condensation of the gas obtained by this process is effected exposes the workers who do it to chlor-acne (see the article "Chlorine"), which is not set up in those who clean the condensation towers of the acid formed by other processes. In the course of filling, of emptying and carrying the carboys (especially when of glass) containing the acid solutions, there is danger from the fumes but especially from the liquid (breakage of the receptacles, splashing).

In course of its use.—Hydrochloric acid is used in a number of industrial operations: manufacture of chlorine, ammonium chloride, acetic acid, carbon dioxide and organic chlorine compounds; preparation of fatty acids; manufacture of glue and phosphates (separation of the gelatin and action on the bones); purification and regeneration of animal black; manufacture of glucose and paper; chrome tanning; carbonising of woollen rags (i.e. destruction of the vegetable fibres in rags in shoddy manufacture, a process that has often constituted a nuisance to the neighbourhood); manufacture of barytes white and several other pigments.

The dyeing industry (bleaching of textile fibres): preliminary treatment with dilute acid, of cotton, linen, hemp and jute; treatment of soft silk by dilute aqua regia, and of tussore silk by dilute hydrochloric acid; dyeing of cotton; preparation of the colouring matter by diazotisation in a bath of nitrite of soda and hydrochloric acid.

Preparation of aniline (by the action of iron filings and hydrochloric acid on nitrobenzene); of numerous other organic bodies by analogous reductions; manufacture of aniline chloride by mixing hydrochloric acid with aniline oil; preparation of acetic acid (4 parts of hydrochloric acid at 22° Be and 1 part nitric acid at 36 Be) to dissolve gold and platinum; treatment of ores of various metals (copper, nickel, cadmium, zinc, bismuth, etc.); in the cleaning of metals; soldering of sheet iron, zinc, brass, copper, tin; dipping of iron articles (utensils) before enamelling; tinning, galvanising, in a liquid known under the name of "spirits of salt"; bronzing of copper and steel; cleaning articles before subjecting them to electro-plating, and cleaning empty bottles with the dilute acid.

In the course of certain operations which give off hydrochloric acid vapour: use of acid solutions; roasting of minerals containing copper and

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1 In the tinning industry spirits of salt (French, esprit de salpêtre) Italian, spirito del sale). For cleaning purposes is made by dissolving fragments of zinc in hydrochloric acid. This more or less acid solution of chloride of zinc often causes ulceration of the skin owing to its corrosive action.
zinc; manufacture of cement and of artificial manure (superphosphates); salt-glazing of pottery (see the article "Pottery"); manufacture of chloride of zinc. Formerly dense fumes were given off in the preparation of soda in the Leblanc process (now mostly replaced by the Solvay process) when hydrochloric acid was used for the manufacture of chlorine. While hydrochloric acid was then the residue of the soda industry, to-day the residue is sulphate of soda.

The use of hydrochloric acid containing arsenic occasionally causes poisoning by arseniuretted hydrogen gas (see that article).

**STATISTICS**

These are few. According to Leymann (1906), 853 workers in German factories for the manufacture of hydrochloric acid, Glauber salts and sulphate of soda, for the period 1881-1904, showed the following morbidity figures per 100 workers: 2.2 for diseases of the nervous system; 14.9 for respiratory diseases; 22.6 for digestive diseases; 10.1 for infectious diseases; 4.3 for burns; 9.1 for other injuries; 20.2 for diseases of the locomotory system; 6.2 for skin diseases; 0.9 for organs of the special senses; 0.2 for venereal diseases. Cases of sickness affected 91 per cent. of the workers and the duration of invalidity per worker lasted 10.5 days.

Among cases described by factory inspectors or reported in connection with compensation are the following: Bavaria, 1914-1918, 8 cases (including those caused by sulphuric acid); 1919, 1 case. Switzerland, 1911, 17 cases; 1912, 6; 1915, 9; 1916, 14 (including those due to hydrofluoric acid); 1917-1918, 21 cases (including those due to other acids); 1920, 5 cases of poisoning and 1 of ulceration; 1921, 3 cases of ulceration. (See also article "Chlorine").

**SYMPTOMS**

**Intoxication by the vapour.**—In feeble concentration the vapour irritates the respiratory tract. When the concentration exceeds 0.05 per cent., and acts for some time, or with higher concentration, or after repeated inhalations, signs of chronic irritation of the respiratory mucous membrane show themselves, such as conjunctivitis, sneezing, pharyngitis, laryngitis, bronchitis and sometimes haemorrhages from the lungs and digestive tract. In lead solderers (in the United States) inflammation of the nasal mucous membrane developing into ulceration of the septum is said to have been observed. According to Hirt, affections of the digestive tract are more frequent than those of the respiratory. Only very rarely does it occur that very high concentrations bring about loss of consciousness and death.

Dental lesions (see also article "Mouth and Teeth") demonstrate the chronic action of the acid vapours. The result is a molecular necrosis of the most exposed teeth (incisors), which become soft, weak and friable. These lesions affect most frequently workers engaged in the manufacture of sulphate of soda and hydrochloric acid (Leblanc process), and especially those who habitually hold between their teeth (as a supposed protection) a piece of flannel on which the vapour rapidly condenses. Caustic effects of the gas on the edge of the tongue have been reported. (For acne, see article "Chlorine").

**Lesions set up by the solutions.**—As a result of the acute action of solutions of hydrochloric acid, erythemas and burns are set up which, according to Prosser White, if immediately washed are less dangerous than those set up by sulphuric and nitric acids. On the other hand, the health of workmen coming into contact with hydrochloric acid is said to be less satisfactory than that of workmen in sulphuric and nitric acid plants (Lehmann).

Chronic effects are seen in sharply defined ulcerations of the skin varying in size, or, when the effect is less pronounced, of whitish papules with slight necrosis. An inflammation also of the edge of the eyelids and conjunctivae is reported.

**DIAGNOSIS**

This presents no difficulties.

**DEMONSTRATION**

The quantitative estimation of hydrochloric acid vapour in the air is sufficiently easily effected by Mohr's method (passage of the gas to be analysed through a solution of soda free from chlorine and titration by means of silver chloride with the addition of neutral potassium chromate to serve as an indicator).

**HYGIENE**

**In the factory.**—Measures should be taken to secure satisfactory working of the furnaces. The apparatus should be airtight and the pipes protected against escape of gas. Apparatus should be placed under large hoods so arranged as to remove the gas as far as possible. The hydrochloric acid gas should be condensed or absorbed as completely as possible and the escape of residual gases through the chimney-stack restricted. When conducting
the Leblanc process the acid should not be introduced until the charge of salt has been completed and the furnace doors tightly closed.

The workrooms should be well ventilated. The floors should be of cement, and discharge of the acid liquors on to public ways or into water courses should be prohibited. In any case all escaping liquor should be neutralised with chalk or lime. The carboys should be provided with clay stops. (For manipulation of the carboys and pouring out of the acid, see the article "Acids ")

First aid.— Neutralise immediately with alkaline solutions the acid splashes on the worker's skin

LEGISLATION

Employment of persons under 16 years of age is forbidden in Belgium; under 18 in France (in places where acid fumes are evolved and where acids are manipulated) and in Switzerland: boys under 15 years in Italy and Japan; under 16 years in Spain, Greece, Province of Quebec; girls under 18 years in Greece and Province of Quebec; women under 21 years in Spain, Italy and Japan.

Poisoning and lesions set up by hydrochloric acid receive compensation as accidents in Switzerland and the State of Missouri (United States). (See also article "Acids ")

Hoverny Cynanid (Prussic Acid)


CHEMISTRY

Hydrocyanic acid, of which the formula is $HCN$ or $HCy$, is the nitrile of formic acid. When pure it is a colourless liquid with a strong smell of bitter almonds; it is very volatile, burns with a violet flame, fuses at $-14^\circ$ C and boils at $+26.1^\circ$ C. Its density (at $18^\circ$ C) is 0.697. It is very soluble in water and alcohol; the solution decomposes spontaneously and very rapidly. On the contrary, solutions in distilled water last some time. The watery solution does not redden litmus paper.

The pure anhydrous acid is very stable; it is a laboratory product very little used. It is found in nature, in certain fruits, or it is formed as a product of decomposition of amygdaline or other glucosides contained in the grains of numerous vegetables. It is obtained artificially starting from gaseous ammonia and carbon heated to $1,000^\circ$ C; from acetylene and nitrogen by means of the electric spark; from ammonia and carbon monoxide; on contact with spongy platinum; from ferrocyanide of potassium treated with a hot solution of dilute sulphuric acid.

Manufacture

(See also article "Cyanogen ")

Industry, hydrocyanic acid is obtained:

(a) from the cyanogen compounds contained in illuminating gas (300 to 600 grm. per ton of coal distilled), blast furnace gas and coke ovens. The compounds are fixed either by a dry or wet depuration process, and converted into ferrocyanide (see the article "Cyanogen ");

(b) by distillation of the yellow prussiate with diluted sulphuric or hydrochloric acid. The residue formed of "sel d'Everitt " and sulphate of potassium forms afresh the yellow prussiate by oxidation of the air in alkaline solution;

(c) from calcium cyanamide (see that article);

(d) from alkaline earthy carbonates heated with carbon and nitrogen (the alkaline earthy cyanides formed when treated with acetic acid yield hydrocyanic acid);

(e) from ammonia, protoxide of nitrogen, and carbon heated together;

(f) from ammonia and various hydrocarbons treated in the presence of a catalyst;

(g) from the residues from the distillation of alcohol, beetroot, molasses, containing about 2 per cent. of nitrogen. Under special fermentation processes this nitrogen yields ammonia and trimethylamine, and the latter heated to $1000^\circ$-$1100^\circ$ C. becomes converted into hydrocyanic acid and methane.

For desinfection purposes hydrocyanic acid is made by dissolving solid sodium cyanide in diluted sulphuric acid (the American regulations, for example, mention 23.54 grm. of cyanide to 42.5 grm. of acid at 66° Baumé and 59 c.c. of water).

Sources of Poisoning

Hydrocyanic acid is given off in many processes of which the most important are the following:

Industrial manufacture (see above);

Manufacture of illuminating gas (see article "Gas-Works ");

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Preparation of poison gas (munitions of war); combustion of cellulose.

Precautions should be taken against escape of hydrocyanic acid in chemical laboratories (Scheele, who discovered the compound, was a victim).

Danger, although remote, has been reported in the following operations:

- Incomplete combustion and distillation of organic compounds;
- Calcination of these matters with carbonate of potassium or sodium in the preparation of alkaline cyanides;
- Exposure of cyanides to the air; decomposition of metallic cyanides (bicyanides of gold and silver) or of sulpho-cyanide of ammonium (by weak acids);
- Gilding and silvering of lacework;
- Preparation of red prussiate and use of this compound for dyeing and mordanting (the residuary waters from these industries also contain hydrocyanic acid);
- Stamping fabric by means of Prussian blue and the so-called French blue (especially in the preparation of the colour);
- Manufacture of sulpho-cyanide and fulminate of mercury (see that article);
- Manufacture of soda by the Leblanc process (hydrocyanic acid and cyanogen are given off when emptying the trolleys of soda obtained in melting in a reverberatory furnace a mixture of sulphate of soda, coal, and limestone);
- Preparation of oxalic acid by treating wood ashes with nitric acid;
- Oxidation of pure albumens by strong nitric and sulphuric acids;
- Extraction of phosphoric acid from bones;
- Electroplating, etc.

Dangerous also are:

- Escape of gas in foundries and brass furnaces (which gas also contains carbon monoxide, sulphur dioxide, and arseniuretted hydrogen);
- Manipulation of the sediment from gas pipes, rich in hydrocyanic acid (the cause, according to German experts, of fatal accidents erroneously attributed to carbon monoxide);
- Work in agers (aniline black dyeing; fumes from aniline and hydrochloric acid); cleaning the ager and setting in place the materials to be treated in the dyehouses;
- Use of powders made from cyanides or hydrocyanic acid for silvering or for cleaning objects of silver, gold, or other metals, etc.

Hydrocyanic acid is used in the solid, liquid, or gaseous form. The most important use is hydrocyanic acid vapour for disinfection and deratization purposes, because no damage is done to the articles treated. The vapour being lighter than air tends to rise; a safety zone of 15 to 20 metres and good ventilation must be ensured. Absorbed by porous materials, entering into solution with substances more or less watery, this vapour is liberated when the surrounding temperature rises and can easily occasion severe and even fatal accidents.

Although certain authorities assert that poisoning by hydrocyanic acid only occurs where indispensable precautions have been omitted, it must be admitted that, even with the full knowledge of the indisputable danger from this gas, negligence will always play a part in accidents from it despite every regulation and every circular. A very grave risk is run by workers on ships who are obliged to expose themselves to an atmosphere charged with overpowering proportions of hydrocyanic acid and to solutions rich in the acid or cyanide of sodium when the atmosphere has not been very thoroughly ventilated.

The concentration of the gas for sanitary work ought not to exceed 10 per cent. Permission to enter places that have been disinfected should depend essentially on the ventilation that can be secured.

In several countries the use of carbon monoxide has been given up because, as it gives no evidence of its presence, it may cause serious accidents. For the same reason it may be necessary to abandon the use of hydrocyanic acid (France, 1922) as being more toxic than carbon monoxide.

For this reason certain countries have proposed and agreed to use hydrocyanic acid mixed with irritating lachrymatory gases, but in proportions just sufficient to detect their presence in the atmosphere (Argentina: suggestions of the Port Sanitary Authorities at the Conference held in London in 1922), or mixed with sulphur dioxide (authorised by the United States since 1910). Cases of poisoning have been reported in America among gardeners who had used hydrocyanic acid to preserve plants and fruits against parasites. The danger is greater among persons connected with scientific laboratories (inhalation of the vapour). In addition, mention should be made of cases due to accidents: breakage of containers, etc.; and escape of the contents, use of hydrocyanic acid in crystals to remove silver nitrate, this danger being frequent among chemists and photographers. The cases reported among medical men
following on autopsies are extremely doubtful (see article "Cyanogen").

**TOXIC ACTION**

The fatal dose of the pure acid is 0.15 grm., that of the pure anhydrous acid 0.06 grm. Hydrocyanic acid has no effect on cats at 0.03 or 0.04 mg. per litre (even during four or five hours). Severe symptoms appear in them with air containing 0.05 mg. of acid per litre of air if inhaled for 1 to 1½ hours; death supervenes after 2½ to 5 hours. At 0.12-0.15 mg. per litre it is fatal after 30 minutes. Lehmann regards 60 mg. as the minimum fatal dose for man, i.e. 0.8 to 1 mg. per litre, but the minimum toxic dose for man is not known in practice; 0.06 mg. per litre of air it is thought could be inhaled for a long time without damage, but severe cases of poisoning have been reported with a percentage of 0.04 mg. per litre.

According to Lehmann (1912) 300 parts of gas per million of air rapidly kill animals and man; Kohn-Abrest (1915) is of opinion that 1,000 parts per million could only be breathed for a few minutes. Researches undertaken in the United States (1923) show that air containing 1,000 parts per million kills rats in ten minutes, while air inhaled for ten minutes containing 500 parts per million does not kill them. The conclusion is that air containing less than 500 parts per million could be breathed by man for one minute.

Although exposure to inhalation of the poison should not be incurred by workers unless provided with a breathing apparatus, nevertheless, if a man, aware of the danger, should by chance enter without such protection an atmosphere where hydrocyanic acid is present in a proportion exceeding 100 parts per million he must not authorise the entry of other unprotected persons unless the proportion of gas is less than 100 parts per million.

All channels — skin and mucous membranes included — allow of absorption of the compound. The gas may even be absorbed by the unbroken skin. Experiments by Lehmann on chemists (dipping their fingers into a solution of hydrocyanic acid) prove that very severe symptoms may be observed in a very short time.

Hydrocyanic acid is a fulminant poison. Like cyanogen (C. N.) it is poisonous to the protoplasm of the ferments, and has a paralysing action on the blood system. On warm-blooded animals the gas and the acid exert a gradual but different action: the acid is two to five times as powerful as the gas. Inversely, the latter has a stronger local irritating action on the skin and mucous membranes and sets up a distressing anaesthesia. The cerebral troubles set up by the gas are less serious than those resulting from the acid.

The action on man and the higher animals is very complex: there is a local action, slight yet constant, on the peripheral nerve endings; a stronger action on the central nervous system: transitory irritation followed by paralysis (centre of vagus, heat-regulating centre, vaso-motor and respiratory centres). With large doses: paralysis of all the centres together, without the irritating action above referred to (in the strictest sense of the word a bulbar poison). At this stage the heart still functions and the paralysis can be overcome by artificial respiration.

**Effect on nutrition.** — The organism absorbs less oxygen, and forms less carbon dioxide which is found in excess in the interior organs where it brings about a real asphyxia; arterisation or oxygenation of venous blood, which is transitory in the case of warm-blooded animals, has been reported.

**Action on the blood.** — Hydrocyanic acid in the blood diminishes the alkalinity; causes the presence of lactic acid; colours the skin a bright red at certain places and everywhere else a dark red (according to some writers this colour depends on the amount of hydrocyanic acid contained in the blood, because, even in small quantity, it does not allow the blood easily to part with its oxygen; according to others it is due to the presence of ammonia in the blood and according to Kobert to cyanmethaemoglobin, which has a fine red colour). The respiratory function of the blood is at any rate profoundly modified and this can be proved in vitro.

Blood containing hydrocyanic acid loses its power of decomposing oxygenated water, i.e. of acting catalytically. Hydrocyanic acid acts even in minimal doses on a solution of methaemoglobin, making it red as does the oxide of nitrogen; at the same time the spectrum of methaemoglobin disappears (with its characteristic band in the red) and brings into view an absorption band with ill-defined edges in the green. The cyan-methaemoglobin of Kobert is observed also with the gas, a cyanhaemoglobin which, under certain conditions, can be decomposed further into haemoglobin and oxyhaemoglobin. Lastly, according to Hoppe-Seyler, hydrocyanic acid combines with alkaline haematin, yielding cyanhaematin which does not decompose into haemoglobin and oxyhaemoglobin.
HYDROCYANIC ACID — 996 —

The heart fails only at the end from the action of the poison. Sugar, lactic acid, and blood are to be found in the urine.

In an autopsy on a case of poisoning the surgeon who made it (in Great Britain, 1923) did not detect the characteristic smell of the poisoning on opening the body, but the smell was noticed in all the serous cavities and especially in the lateral ventricles. Signs of putrefaction and the usual coloration of the skin were absent, as were also the characteristic reactions of the poison to chemical and spectroscopical tests.

Elimination.— This occurs partly by the lungs as unchanged acid, in traces by the sweat and, rarely, by the urine.

Immunity.— Reference is made to a certain degree of acclimatisation, but this is scouted by toxicologists.

STATISTICS

Although the product is so well recognised for its toxicity, and is one evolved fairly frequently in industrial processes, cases of industrial poisoning are rare. Relatively more frequent are the cases of acute poisoning following an accidental escape of gas, celluloid fire, etc.) or rash entry into poisonings following an accident (escape of hydrocyanic gas emitted during the decoction of arsenic and cyanide of potassium. A case of poisoning due to cyanogen in an artificial manure factory in Baden is doubtful.

From 1914 to 1918 one case of poisoning was reported in Bavaria, and in 1919 at Düsseldorf massive intoxication occurred from the disinfection of a working class house. Similarly in Baden, in a factory for making hydrocyanic acid for disinfection purposes (by acting on sodium cyanide with sulphuric acid) the workers were affected. Even the workmen wearing Drager apparatus and goggles (worn with great reluctance) suffered from slight conjunctivitis. In 1923, one chronic case was described by J. Rosenbloom (St. Louis, U.S.A.) and two fatal cases by T. G. Seager (Great Britain), three fatal cases in Belgium (Antwerp, 1923), etc. (See also the article "Electroplating").

SYMPTOMS

The onset in the acute form is rapid; but this rapidity has certainly been exaggerated. In the initial stages of the acute and subacute forms subjective symptoms are prominent: vertigo, psycbical manifestations, headache, salivation, sense of constriction in the throat, swelling in the head, precordial anxiety, palpitation, hurried breathing, inability in the visual field, air hunger. Further, there may be irritation of the conjunctiva, vomiting, and cyanosis. When the acute form is very severe a second stage follows characterised by respiratory trouble, asthma, prolonged and very deep expirations succeeded by long pauses, cyanosis, tremor, and nephritis appeared on the ninth day in one case. Consciousness remains unaffected.

The third stage is characterised by violent cramps, muscular relaxation, superficial breathing, complete unconsciousness, apnoea, irregular and intermittent heart-beat.

In some cases, rapidly fatal, a fourth stage can be observed with dilated pupils, symptoms of asphyxia, and death from coma.

In case of recovery sequelae may result: headache, debility, heart weakness, circulatory troubles, arhythmia, bradycardia, vertigo, motor troubles, insomnia.

Chronic poisoning, due mainly to the cyanides of potash and silver, is said to be characterised by respiratory and gastric disturbance, headache, drunken gait. These cases, which some authorities do not recognise, are said to have
been observed among persons who have worked many years at electroplating (see that article) in badly ventilated rooms. In addition to very slight symptoms (ocular oppression, dryness of the throat, dull epigastric pain), sometimes insignificant, a cutaneous eruption, like a acne rosacea, redness more or less pronounced of the face, pharyngeal mucous membrane and conjunctiva, have been observed. Probably the small quantities of hydrocyanic acid introduced into the system are converted into harmless products easily eliminated by the saliva and urine.

**Cutaneous lesions.** — (See articles "Cyanogen" and "Electroplating"). Epitheliomatous ulcerations also have been reported in persons engaged in electroplating.

**DIAGNOSIS**

In the culminating cases the rapidity with which death ensues assists in the diagnosis. In acute cases coma supervenes early: there is the characteristic smell of the breath and eructations. Sometimes, however, diagnosis is very difficult. (See article "Cyanogen").

**DEMONSTRATION**

1. In the atmosphere.

(a) Dip filter paper in fresh tincture of guaiacum (3-4 per cent. of resin). After evaporating the alcohol moisten with a 25 per cent. solution of sulphate of copper. A trace of hydrocyanic vapour will turn the paper blue as a result of the action of the active oxygen liberated.

This is an extremely sensitive test, but not quite decisive because ammonia, nitric acid, ozone and iodine give it also.

(b) Pertusi Gastaldi reaction: a solution of nitrate of copper (0.25 per cent.) mixed with an equal quantity of a solution of acetate of benzidine (0.25 per cent.). Filter paper soaked in this solution (which will not keep long) turns blue if the air contains hydrocyanic vapour. The test is very sensitive and reveals rapidly 0.1 mg. of vapour per litre of air and 0.05 mg. in a million of air. Titration follows with a deci-normal solution of silver nitrate in presence of potassium chromate (1 c.c. = 2.7 mg. of hydrocyanic acid). The acid solution can also be titrated, after neutralising it with hydrocyanic sulphide, etc., with a deci-normal solution of iodine (1 c.c. = 1.35 mg. of hydrocyanic acid).

The Minister of the Interior of the State of Pennsylvania has recently (1923) requested the Bureau of Mines in Pittsburgh to investigate the best means for demonstrating the presence of hydrocyanic acid in the air. The station has even prepared an apparatus for the analysis of the air using a colometric method (with guaiacum) capable of showing the presence of 25 to 1,000 parts in a million of air.

In the course of the enquiry the Station proved that the reaction with filter paper dipped in an aqueous solution of picric acid (1 per cent.), and after drying in a solution of sodium carbonate (10 per cent.), is not reliable, because it is affected by several compounds (hydrogen sulphide, acetone, aldehydes, etc.). The same defect underlies the reaction based on phenol phthaline, which shows 0.5 of a million of hydrocyanic acid in the air, but which is deranged also by the fumes of chlorine, bromine, hydrocyanic sulphide, etc.

The best test is the physiological one with caged animals. The cat is very helpful, mewing and scratching the woodwork in concentrations readily tolerated by man. Generally, rats and mice are used.

For flame and micro-chemical tests, see article "Cyanogen".

2. In the body.

Hydrocyanic acid decomposes sometimes rapidly, at others slowly, but generally a certain length of time elapses before all the hydrocyanic acid absorbed is decomposed (about two days). No time, however, should be lost, because during putrefaction cyanogen combinations may take place, such as hydrocyanic acid or potassium cyanide. Analysis should include the stomach and intestines of the dead man. Generally, rats and mice are used.

**HYGIENE**

General ventilation of workrooms and exhaust ventilation locally applied at the point where vapour is generated is required.

As regards disinfection by means of hydrocyanic gas, it would be best to
Hydrocyanic acid is sold in glass ampoules sealed and packed in boxes containing enough infusorial earth and chalk to absorb and neutralise the acid in case of a breakage (South Africa). Sometimes it is sold in ampoules enveloped in a fine metallic sheet and all that is required is to throw the ampoule against something hard in the place to be disinfected. The metallic sheet holds the fragments of glass; volatilisation is immediate. Trust should never be placed in the sense of smell to judge if aeration has been sufficient as accidents have occurred by so doing.

The sale of substances for silvering and cleaning metals containing cyanides should be regulated.

**Legislation**

See the articles cited above under the heading "Sources of Poisoning".

No special regulations have been enacted, but those against toxic substances generally have force.

For statutory regulations relating to the use of hydrocyanic acid for the deratisation of ships, see "Bibliography".

**Compulsory notification.**—Cases of cyanogen poisoning (Netherlands). In countries demanding notification of cases of gas poisoning. In Belgium disinfection operations on board ships effected by private companies are subjected to industrial inspection (technical and medical). The workers employed by such companies consequently come under the scheme of compulsory accident insurance.

Compensation as an industrial accident. — Japan (dermatitis), Switzerland (cyanogen), Western Australia.

**Bibliography**


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discard it or to entrust its execution to some responsible association.

In the United States hydrocyanic acid has been replaced by cyanogen chloride — not that the latter is less toxic, but its action as a lachrymatory has the advantage of giving warning of its presence in the air.

Sulphuric acid must not be suddenly poured over potassium cyanide in block form, for such blocks become surrounded with a gangue of potassium sulphate, while the centre of the block continues to retain unconverted cyanide. When the recipients are removed the layer of sulphate crumbles allowing the free acid to attack the cyanide with an escape of gas sufficient to cause death. The salts should therefore be used in solution with an excess quantity of free acid. The mixing of the acid and the salt should be effected in such a manner that contact only occurs after the lapse of a given time.

To prevent explosions the mass should be brought slowly into contact with the acid, and dilute acids only should be used.

Disinfection operations should, in principle, only be effected after withdrawal of the personnel. The operators should be furnished with masks and oxygen reservoirs. The emission of acid should be accurately timed in such a way as to permit the operators to retire before the escape of poisonous gas commences. The quantity of acid used should exceed by 30 per cent. the quantity required for total decomposition of the weight of cyanide employed. The best ventilation possible should be assured over a period of four to six hours at least. The company's chemist and the operator furnished with masks should always make a preliminary analysis of the air before permitting the personnel to enter the holds.

Ventilation, proposed as a method of eliminating the vapour in a room does not offer a sufficient guarantee of safety. As a matter of fact ventilation is difficult or impossible in certain premises and places, because porous substances, which absorb the gas, hold it for a long time, and account for deferred cases of poisoning. Neutralisation of the gas by aldehydes or sodium thiosulphate, of which the experience is said to be pretty conclusive, has also been proposed.

Compulsory use of effective respiratory apparatus kept in good order (see article "Breathing Apparatus"). All contact of the hands, especially with hydrocyanic acid, when dissolving the acid and its compounds should be prohibited.
Hydroxylamine


Hydroxylamine (NH₂, OH) takes the form of colourless deliquescent crystallised needles, melting at 33° C. into a liquid which boils at 58° C. (at a pressure of 22 millimetres of mercury). It is very soluble in water giving an inodorous solution with an alkaline reaction, which is very poisonous. It explodes if heated rapidly to about 100° C.

It is obtained in the form of hydrochloride of sulphate in treating it at a low temperature with sulphur dioxide, concentrated solutions of nitrite and carbonate of soda or calcium nitrite and bisulphite. It can also be obtained electrolytically by reducing nitric acid in presence of sulphuric or hydrochloric acid.

Whilst the free base is of no special use the hydrochloride (NH₂ OH. HCl) and the sulphate [(NH₂ OH). H. SO₄] are used in chemical laboratories, as reagents in organic chemistry, in the perfumery industry for purifying aldehydes and ketones, in the pharmaceutical industry (anti-parasitic anti-septic products, etc.). The nitrate (NH₂ OH NO₃ H) has been recommended for the explosives industry.

The phenylated compounds of hydroxylamine are also of very slight interest from the point of view of industrial hygiene. As regards injury caused by phenylhydroxylamine only one case, reported by Hirsch and Edel, is known. It was that of a student who in course of an experiment spilt 300 grammes of the product on his abdomen and thighs. He suffered from collapse, methaemoglobinaemia and coma lasting several hours. It is possible to understand the clinical picture when it is remembered that the product in question is obtained by weak oxidation of aniline or in reducing with precaution nitrobenzene with zinc powder and water. In practice the product in question is the beta-phenylhydroxylamine, the formula of which is C₆H₅. NH. OH.

The high toxicity of hydroxylamine is due to its intense reducing action. It is considered as a poison of the protoplasm (Löw) and of the blood in which it provokes the formation of methaemoglobin with all its consequences. It is said to produce also violent excitement followed by depression (G. Bertoni and C. Raimondi). According to Binz, hydroxylamine becomes oxidised in the system in the state of nitrites equally poisonous, the salts of which are found in the urine. Pohl mentions also the appearance of allantoin in the urine as in poisoning by hydrazine.

Locally hydroxylamine exercises a caustic action which may lead to the formation of dermatites. Contact with the skin is said to be sufficient to give rise to albuminuria (Lewin).

Injuries due to hydroxylamine are compensated as accidents in Switzerland.

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ERRATA


BUILDING TRADE, p. 327, col. 1: Last paragraph of article should read: Compensation for miners' phthisis in South Africa was extended in 1926 to cover surface bricklayers and surface stonemasons who generally work at the surface of the mine, but whose duties take them underground periodically.


Error in alphabetical order. The article "Fatty Substances" has been placed in error before "Fatigue in Industry" and "Fatigue Tests".