

International Labour Office Geneva

**Radiation  
protection  
of workers  
(ionising radiations)**



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The International Programme for the Improvement of Working Conditions and Environment (PIACT) was launched by the International Labour Organisation in 1976 at the request of the International Labour Conference and after extensive consultations with member States.

PIACT is designed to promote or support action by member States to set and attain definite objectives aiming at "making work more human". The Programme is thus concerned with improving the quality of working life in all its aspects: for example, the prevention of occupational accidents and diseases, a wider application of the principles of ergonomics, the arrangement of working time, the improvement of the content and organisation of work and of conditions of work in general, a greater concern for the human element in the transfer of technology. To achieve these aims, PIACT makes use of and co-ordinates the traditional means of ILO action, including:

- the preparation and revision of international labour standards;
- operational activities, including the dispatch of multidisciplinary teams to assist member States on request;
- tripartite meetings between representatives of governments, employers and workers, including industrial committees to study the problems facing major industries, regional meetings and meetings of experts;
- action-oriented studies and research; and
- clearing-house activities, especially through the International Occupational Safety and Health Information Centre (CIS) and the Clearing-house for the Dissemination of Information on Conditions of Work.

This publication is the outcome of a PIACT project.

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**Radiation protection of workers  
(ionising radiations)**



An ILO code of practice

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International Labour Office    Geneva

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## Preface

In accordance with the decisions taken by the Governing Body of the ILO at its 231st Session (November 1985), a meeting of experts was held in Geneva from 16 to 23 September 1986 to examine and approve a code of practice for the radiation protection of workers (ionising radiations). The meeting was composed of four experts appointed after consultation with governments, four experts appointed after consultation with the Employers' group and four experts appointed after consultation with the Workers' group of the Governing Body.<sup>1</sup>

This code contains a set of practical recommendations on the protection standards to be observed in all activities involving the exposure of workers to ionising radiations. It

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<sup>1</sup> The following experts took part in the meeting:

*Experts appointed after consultation with governments:*

- Mr. P. Beaver, H.M. Superintending Inspector, Health and Safety Executive, London (United Kingdom).  
Dr. D. Beninson, Director, Nuclear Installations Licensing, National Commission for Atomic Energy, Buenos Aires (Argentina).  
Dr. E. Kunz, Head of Radiation Hygiene Centre, Institute of Hygiene and Epidemiology, Prague (Czechoslovakia).  
Mr. Li Deping, Professor, Director of Institute for Radiation Protection, Ministry of Nuclear Industry, Taiyuan Shanxi Province (China).

*Experts appointed after consultation with Employers:*

- Dr. Hoegl, Member of Technical Department, Siemens AG, Erlangen (Federal Republic of Germany).  
Mr. P. W. Mummery, Director, Health and Safety, British Nuclear Fuels plc, Warrington (United Kingdom).  
Dr. E. V. Sollet Sañudo, Chief of Radiological Protection of Nuclear Power Stations, Association of Occupational Medicine and Safety of UNESA for the Electrical Industry (AMYS), Madrid (Spain).  
Mr. M. Sonter, Radiation and Safety Superintendent, Roxby Management Services, Parkside (Australia).

*Experts appointed after consultation with Workers:*

- Dr. R. Owen, Medical Adviser, Trades Union Congress, London (United Kingdom).  
Dr. P.-M. Paris, Occupational Physician, General Confederation of Labour, Montreuil (France).  
Mr. F. Rapp, Chief, Health and Safety Staff, United Automobile Workers, Detroit, Michigan (United States).  
Mr. M. Takahashi, Member of the Executive Committee, Japanese Federation of Electrical Machine Workers' Unions, Tokyo (Japan).

The following international governmental and non-governmental organisations were represented:

*International governmental organisations:*

- World Health Organization.  
International Atomic Energy Agency.  
Commission of the European Communities.  
Arab Labour Organisation.

*Non-governmental organisations:*

- International Organisation of Employers.  
International Confederation of Free Trade Unions.  
International Federation of Chemical, Energy and General Workers' Unions.  
International Metalworkers' Federation.  
International Commission on Radiological Protection.  
International Radiological Protection Association.  
International Social Security Association.  
International Electrotechnical Commission.

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is especially intended for all those with a responsibility in this field, in both the public and private sectors, who may be called upon to draw up instructions on the subject.

Although drafted in the form of regulations, the provisions of the code have no legal force and do not entail any obligation for member States to bring their legislation into conformity with them. Furthermore, they are not intended to replace the provisions of national laws or regulations, or the standards in force. They aim rather to serve as a practical guide for public authorities and services, employers and workers concerned, specialised radiation protection bodies, enterprises and safety and health committees.

The provisions lay down general principles and indicate the different aspects that should be covered by an effective radiation protection programme. They are not meant to be applied as they stand in all countries and regions, but should be interpreted to take account of the local situation, technical resources and scale of installations, factors which will determine the potential for application. In this respect, due consideration has been given to the use of the code in developing countries.

The text of the code was approved for publication by the Governing Body of the ILO at its 234th Session (November 1986).



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## 1. Scope

1.1. The provisions of this code apply to all activities involving the exposure of workers to ionising radiations<sup>1</sup> at work. Additional guidance can be found in documents dealing with special occupational groups and working situations.<sup>2</sup>

1.2. The provisions of this code offer guidance for the protection of workers against radiation risks from radiation sources at the workplace.

1.3. The code covers the principles of dose limitation for workers but it does not include detailed guidance on the techniques used for the actual measurement and assessment of exposures and for their control. Such guidance is being prepared by the International Atomic Energy Agency (IAEA) in co-operation with the World Health Organization (WHO) and the ILO.

1.4. It should be kept in mind, however, that the choice of techniques for control of doses to workers should be made while taking into consideration the presence of other, possibly more serious, chronic or acute risks in the workplace. It is therefore important that actions taken to reduce radiation doses at a workplace should not be such as to increase other occupational safety or health risks.

1.5. The provisions of this code are based on the current recommendations of the International Commission on Radiological Protection (ICRP) and on *Basic safety standards for radiation protection*.<sup>3</sup>

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<sup>1</sup> Unless otherwise specified, the use of the word "radiations" means "ionising radiations".

<sup>2</sup> ILO/IAEA/WHO: *Manual on radiation protection in hospitals and general practice*, 5 vols. (Geneva, WHO, 1974-80).

<sup>3</sup> IAEA/ILO/NEA(OECD)/WHO: *Basic safety standards for radiation protection, 1982 edition*, Safety Series No. 9 (Vienna, IAEA, 1982).

## **2. General duties and responsibilities**

### **2.1. Role and responsibilities of competent authorities**

2.1.1. The responsibilities of the competent authority (or authorities) concerned with radiation protection, their terms of reference and their functions should be clearly defined and promulgated.

2.1.2. The competent authority should formulate the necessary criteria, standards and regulations for radiation protection in consultation with the representative organisations of employers and workers concerned.

2.1.3. The competent authority should establish a system for notification, registration or licensing as required in section 3.1.

2.1.4. The competent authority should provide general guidance necessary for the implementation of the requirements.

2.1.5. The competent authority should provide a scheme for the recognition of approved medical practitioners.

2.1.6. The competent authority should establish a system of inspection to ensure that the measures taken are in compliance with the relevant requirements.

2.1.7. The competent authority should prescribe the content of periodic reports from employers, in which occupational doses are reported for the purpose of determining compliance with requirements, including the requirement that all doses be kept as low as reasonably achievable.

2.1.8. The competent authority should prescribe the manner in which accidental exposures, particularly those which have resulted or are expected to result in doses in excess of the limits, should be reported.

2.1.9. The competent authority should assume the necessary power to intervene in cases of non-compliance with the relevant requirements.

### **2.2. Duties and responsibilities of employers**

2.2.1. The responsibility for providing adequate protection of workers against radiations rests with the employer, even if the employer is himself a subcontractor.

2.2.2. (1) When two or more employers undertake activities simultaneously at one workplace, they should collaborate in order to ensure compliance with national regulations. This collaboration does not relieve the employer of the duty to secure the health and safety of his employees.

(2) General procedures for this collaboration should be prescribed by the competent authority, and each party should understand fully the extent of its own responsibility and should co-operate with the other parties concerned.

(3) Such arrangements should concern in particular:

## General duties and responsibilities

- (a) subcontractors working in a given installation;
- (b) an employer who engages workers in work in controlled areas of several installations.

(4) In the latter case, the employer should in particular collaborate with the different employers of the various installations in order:

- (a) to obtain information concerning the workers' dose equivalents received during the execution of their work in the various installations; and
- (b) to know, for the workers that commence work, the individual dose equivalents for the current year received during their work in other installations.

2.2.3. The employer should follow the procedures for notification, registration or licensing as laid down by the competent authority.

2.2.4. The employer should make the administrative and organisational arrangements necessary for controlling, the exposure of workers to radiations and radioactive materials. He should therefore appoint the appropriate staff, provide the necessary protective equipment, including radiation-measuring systems, maintain buildings, installations and workplaces, and organise work in such a way as to ensure that the radiation exposure of each worker, including his internal exposure, is controlled and complies with the provisions of this code.

2.2.5. The employer should structure the administrative and organisational arrangements in such a way that they operate in a smooth manner and that an effective safety programme consistent with the requirements of this code is implemented.

2.2.6. The employer should establish a policy for the protection of the health and safety of workers, comprising appropriate measures, during planning and operation, to prevent any unnecessary exposure in the installation under his control.

2.2.7. The employer should provide previously defined information to the competent authority, consistent with their respective responsibilities.

2.2.8. The employer should take all necessary steps to restrict occupational exposures resulting from justified practices so that they are "as low as reasonably achievable, economic and social factors being taken into account", and within the constraint of individual dose limits.

2.2.9. The employer should provide radiation surveillance and health surveillance as required in Chapter 7 of this code. The arrangements should be clearly defined and made known to the competent authority, and to the workers concerned and their representatives.

2.2.10. The employer should comply with the authorised limits for any radiation quantity specified by the competent authority.

2.2.11. The employer should conduct regular safety and radiation protection inspections at suitable intervals, to ensure that the provisions of the dose limitation system prescribed in paragraph 5.1.1 of this code are adhered to.

2.2.12. The employer should provide for the appropriate instruction, information and training of workers which will enable them to carry out their work in accordance with the requirements of radiation protection regulations. This should include information on the health hazard, if any, associated with their work, the precautions to

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be taken and the importance of complying with medical and technical requirements, as well as appropriate training in the field of radiation protection.

2.2.13. The employer should ensure compliance with the requirements of radiation protection; when necessary, he should assign radiation protection surveillance functions to individuals in line management.

2.2.14. When work is carried out jointly by a number of persons, the employer should ensure that all workers understand their separate and joint responsibilities for controlling the exposure of others, as well as of themselves, to radiation and radioactive substances, and should see that they are adequately supervised.

2.2.15. The employer should establish an emergency plan based on the actual conditions of the installation so that appropriate realistic remedial action can be taken in the event of a radiation accident.

2.2.16. The employer should establish and keep records as required by the competent authority to demonstrate compliance with the radiation protection programme.

## **2.3. General duties of workers**

2.3.1. (1) Workers should follow, as instructed by the employer, all rules, regulations and working procedures for the control of exposure to radiations and radioactive materials in the working environment in order to protect their own health as well as that of their colleagues.

(2) Workers should take all reasonable measures, for example by preventing contamination and avoiding unnecessary exposure, to keep their own radiation exposure and that of others to the minimum consistent with their duties.

2.3.2. (1) Workers should always make proper use of:

- (a) all safeguards, safety devices and protective equipment made available to limit their exposure and that of others to radiations and radioactive materials; and
- (b) personal dosimeters and other exposure-monitoring equipment provided to assess exposure to radiations and radioactive materials.

(2) In addition, workers should provide biological samples and attend for other exposure monitoring as may be properly required.

2.3.3. No worker should interfere with, remove, alter or displace any safety device or other equipment made available for his protection or the protection of others, or interfere with any method or process of monitoring exposure to radiations and radioactive materials.

2.3.4. Workers should provide information about their job experience with radiation sources so that this knowledge can be used for the improvement of workers' safety.

2.3.5. Workers should submit themselves to health surveillance where appropriate.

2.3.6. Whenever work involves exposure to unsealed sources of radioactive materials, workers should adopt good personal hygiene practices such as the regular use

## General duties and responsibilities

of clean work clothes and showering at the close of work, because these practices help to minimise the intake of radioactive materials.

2.3.7. Workers should use the equipment provided to monitor their place of work, their body, work clothes and personal effects, whenever necessary, before leaving controlled areas in which unsealed sources of radioactive materials are handled or stored.

2.3.8. Workers should ensure the proper use of radioactive materials under their care.

2.3.9. Workers should report to their supervisor any unusual condition at the workplace or affecting installations and equipment.

2.3.10. Workers should report to their supervisor any accident or injury which arises in the course of, or in connection with, their work.

2.3.11. Workers should report immediately to their supervisor and, if available, to the physician in charge of health surveillance, any significant ailment or condition which might, in their view, prevent them from performing their radiation work safely.

2.3.12. Workers should report to their supervisor any suspected over-exposure to external irradiation or any suspected accidental incorporation of radioactive materials.

2.3.13. With a view to the protection of the foetus, female workers engaged in radiation work A (see paragraph 4.4.2) should be advised that they should inform the employer when they know that they are pregnant so that their working conditions may be suitably adapted.

## 2.4. General principles for informing, instructing and training workers

2.4.1. Workers should be informed about:

- (a) the nature and sources of potential health risks which could result from the handling or use of radiation sources;
- (b) the criteria and principles of radiation protection and the control measures to be taken appropriate to their work. This should include information about the safe working methods and techniques to which they should adhere, the proper use, operation and care of personal monitoring and protective devices, personal hygiene measures to be followed to limit the intake of radioactive substances, local radiation protection rules and procedures, including the appropriate first-aid measures; and
- (c) the names of the approved medical practitioner and the radiation protection officer, and the names and addresses of the representatives of the competent authority.

2.4.2. This information should be given and made available as appropriate to workers before they take up their assignments, and at suitable intervals thereafter. Special attention should be paid to newly recruited workers, to those who may encounter language problems and to temporary workers.

2.4.3. (1) Every worker, before starting a new assignment, should be thoroughly instructed in his duties and responsibilities, the sources of exposure to

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radiations and radioactive substances associated with his assignment, and the protective measures and control methods to be followed.

(2) The instructions should include the need for notification of any health problems, and information on appropriate first-aid measures.

2.4.4. Whenever necessary, and in addition to radiation protection rules and procedures, detailed working instructions relevant to the specific radiation work to be performed should be provided in writing.

2.4.5. The instructions referred to in paragraph 2.4.3 should be made available, in an appropriate form, to all workers concerned. Supervisors should ensure that workers are familiar with the contents through appropriate training and periodic retraining.

2.4.6. Radiation protection and operating instructions relevant to the controls adopted for a work area or a job should be posted in a prominent and accessible position or otherwise made available to the workers.

2.4.7. (1) Appropriate training and explanations, including in occupational safety and health subjects, should ensure that workers attain the level of competence required to perform their duties and contribute towards keeping their exposure and that of others as low as reasonably achievable.

(2) Training programmes, including periodic retraining, should be provided to workers as appropriate to their duties and responsibilities, in order to ensure continued competence.

2.4.8. Special attention should be given to ensuring that temporary workers have received the appropriate training and instructions.

2.4.9. Training in emergency procedures should be given to all persons who have specific tasks to perform in an emergency situation. Training exercises for testing the emergency plan should be carried out periodically, involving all site personnel.

## **2.5. Responsibilities of manufacturers, suppliers and vendors**

2.5.1. Manufacturers, suppliers and vendors of articles for use in radiation work in the following categories:

- (a) articles comprising or including a radiation source, unless otherwise exempted;
- (b) articles intended to be used for radiation protection purposes;
- (c) articles for the detection and measurement of radiation; should design, construct or supply, as the case may be, those articles in such a way as to restrict, so far as reasonably achievable, the extent to which workers are or are likely to be exposed to ionising radiations. Such information as may be necessary to further this objective, relating to the proper use and if appropriate the maintenance of such articles, should be provided. The presence of any radiation source incorporated in such articles should be indicated.

2.5.2. Manufacturers should undertake studies and research in order to improve the design, construction and performance of the equipment, materials and facilities supplied so as to contribute to the adequate control of occupational hazards.



## 2.6. Co-operation

2.6.1. (1) There should be full co-operation at all levels between employers, workers and their representatives, radiation surveillance personnel and health surveillance personnel with respect to the radiation protection of workers.

(2) Arrangements should be made to facilitate co-operation between the employer and the workers and their representatives in the enterprise with respect to the radiation protection of workers; these arrangements should include, as necessary, the involvement in radiation protection matters of safety and health committees, where they exist.

2.6.2. The employer should provide the workers' representatives with the opportunity to accompany inspectors in their inspections of occupational safety and health conditions, to take part in investigations into the causes of occupational accidents and diseases and to participate in epidemiological studies.

2.6.3. (1) The employer should consult the workers and their representatives in the appropriate manner on matters relating to the radiation protection of workers and should take appropriate action on the decisions reached in such consultations.

(2) Efforts should be made in particular to:

- (a) ensure that the desired level of radiation protection requirements, instructions and good practice is fully implemented;
- (b) encourage workers to propose improvements in working methods;
- (c) ensure that radiation surveillance personnel and health surveillance personnel pay all due attention to the comments of workers regarding the consequences of the working conditions on their health and well-being.

2.6.4. Co-operation should be established between manufacturers, suppliers and purchasers of machinery, protective devices and equipment so as to ensure compliance with standards and quality assurance requirements.

2.6.5. In order that more effective preventive measures may be taken, the results of experience gained during functioning of installations or in the course of work practices, the results of technological innovation or the results of safety research and development should be examined by employers, workers' organisations, the competent authorities and manufacturers so that they may take the necessary steps for practical implementation as appropriate. This provision would be particularly relevant for the optimisation of radiation protection.

### 3. System of notification, registration or licensing

#### 3.1. General

3.1.1. The competent authority should not authorise the use of a radiation source or permit a practice involving the exposure of workers to radiations at work unless such a source or practice is subject to control by a system of notification, registration or licensing.

3.1.2. Certain practices or sources may be exempted from the requirements referred to in paragraph 3.1.1 if the competent authority considers the inclusion of such practices or sources in the system of notification, registration or licensing unnecessary. The competent authority should specify the conditions under which the exemption is authorised.<sup>1</sup>

3.1.3. In establishing the system referred to in paragraph 3.1.1, the competent authority, taking into account the provisions of the system of dose limitation mentioned in paragraph 5.1.1 of this code, should:

- (a) classify sources and practices according to the requirements of notification, registration or licensing, taking into account the health hazard involved; and
- (b) where licensing is applicable, specify conditions under which a licence can be issued.

#### 3.2. Notification and registration

3.2.1. The competent authority should specify the manner in which the employer should notify or register the equipment, sources and practices involving the exposure of workers to radiations.

#### 3.3. The licensing process

##### General

3.3.1. The competent authority should specify those sources and practices involving exposure of workers to radiations which require a licence.

3.3.2. The competent authority should establish:

- (a) the requirements for the applicant to obtain the relevant licence;
- (b) the procedure to be followed for this purpose; and
- (c) the methods of follow-up to ensure compliance during construction,

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<sup>1</sup> IAEA/ILO/NEA(OECD)/WHO: *Basic safety standards for radiation protection*, 1982 edition, op. cit., gives the general principles that should be considered in specifying the conditions under which the exemption is authorised, together with some possible exemptions. The IAEA is currently considering the subject.

commissioning and operation, including the modification of design or working procedures, and decommissioning as appropriate.

3.3.3. The employer should apply for the appropriate licence according to the procedure prescribed by the competent authority.<sup>1</sup>

3.3.4. The licensing procedure may be considered as an ongoing process starting at the design stage, as required for large installations or large radiation sources, and continuing until decommissioning. It should be connected with the application of the principles of radiation protection to the specific practice being licensed, especially with an analysis of the optimisation of radiation protection. Licensing the introduction of a new practice would also be connected with an analysis of its justification.

3.3.5. The fact that a licence has been granted should not preclude the possibility of changes in the licence during the period of its validity.

#### Requirements for a licence

3.3.6. The applicant has the responsibility for ensuring safety in the planning, design, construction, commissioning, operation and decommissioning of the facility of which he is in charge.

3.3.7. The applicant should demonstrate to the satisfaction of the competent authority that this responsibility is fulfilled.

3.3.8. The applicant should be required to submit and make available to the competent authority in due time the information that the authority requests. He should also be responsible for notifying the competent authority of all new information and of all alterations to previously submitted information which may be relevant to the licensing process.

3.3.9. The competent authority should determine its procedures and requests for information in such a way as to avoid significantly diluting the applicant's overall responsibility for safety.

3.3.10. The competent authority should examine in appropriate detail the applicant's proposal and provide feedback, particularly with respect to design proposals, taking advantage of experience gained in optimisation of radiation protection in similar situations elsewhere.<sup>2</sup>

#### Format of documents and scheduling of submissions

3.3.11. The information referred to in paragraph 3.3.8 should be submitted by the applicant to the competent authority in support of the licensing application. The submission should be in a format that serves the purpose of and is in accordance with the local regulations.

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<sup>1</sup> The licensing process varies in complexity depending on the nature of the source or practice involved and on national law or practice. For example, various stages of licensing may be combined or a partial licence may be granted.

<sup>2</sup> Flexibility in the application of this requirement, according to the nature and size of the facility or practice, should be borne in mind, as well as the practical experience available.

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3.3.12. The extent of the documentation and the stages of its submission to the competent authority may vary greatly according to the complexity and nature of the facility or practice. In general, however, the documents containing the required information may be classified as basic licensing documents, supporting documents and reference documents.

3.3.13. Whenever applicable, and to facilitate smooth review procedures and prevent delays in granting the licence, the information needed by the competent authority at various stages of the licensing process should be submitted in accordance with a prior specification and to an agreed programme. The competent authority should have sufficient time to review all the documents submitted in support of a licence application, to judge its adequacy, to carry out additional discussions with the applicant as required, and to come to a final decision concerning the authorisation.

3.3.14. It is convenient in large and complex facilities to combine the information in a set of documents, known in the nuclear industry as "Safety reports". They should provide the necessary detailed information in a format drawn up in conformity with the requirements of the competent authority and should be submitted according to an agreed schedule.

## **4. Classification of workers, and conditions and areas of work**

### **4.1. Categorisation of workers**

4.1.1. For the purpose of this code there are two categories of workers:

- (a) workers engaged in radiation work; and
- (b) workers not engaged in radiation work, but who might be exposed to radiations because of their work.

4.1.2. Workers engaged in radiation work are workers to whom the dose limits given in paragraph 5.4.3 apply.

4.1.3. Workers not engaged in radiation work should be treated, as far as restricting radiation exposure is concerned, as if they were members of the public.

4.1.4. No person under the age of 16 should be considered to be a worker engaged in radiation work for the purpose of this code.

4.1.5. No worker, student, apprentice or trainee under the age of 18 should be allowed to engage in radiation work in radiation Working Condition A (see paragraph 4.3.1); such persons may only, therefore, work in Working Condition B.

### **4.2. Conditions of exposure**

4.2.1. For the purpose of this code there are two conditions of exposure:

- (a) conditions in which the occurrence of exposure can be foreseen and limited by appropriate control measures; these include exposures under normal conditions of operation and planned special exposures; and
- (b) conditions in which the source of exposure is not subject to control; these include accidental exposures and emergency exposures, i.e. exposures during abnormal conditions where it is urgent to prevent injury or to save life, to rescue injured or trapped individuals and to prevent a substantial increase in the scale of an accident, including the saving of property.

### **4.3. Working conditions**

4.3.1. For the purpose of this code there are two classes of working conditions for workers engaged in radiation work:

- (a) Working Condition A – where the annual exposures might exceed three-tenths of the dose limits (given in paragraph 5.4.3); and
- (b) Working Condition B – where it is most unlikely that the annual exposures will exceed three-tenths of the dose limits (given in paragraph 5.4.3).

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### **4.4. Classification of workers engaged in radiation work**

4.4.1. It may be convenient for radiation control purposes to classify workers engaged in radiation work according to their exposure condition.

4.4.2. The employer should, with the advice of the radiation protection officer, classify workers as:

- (a) workers engaged in radiation work A: these are radiation workers working under Working Condition A;
- (b) workers engaged in radiation work B: these are radiation workers working under Working Condition B.

4.4.3. The employer should keep the classification of workers engaged in radiation work under review to accommodate changes in working practices.

### **4.5. Classification of areas**

4.5.1. The employer should, with the advice of the radiation protection officer, classify all areas of the installation in accordance with the provisions of this code.

4.5.2. A controlled area is an area subject to special rules for the purpose of protection against radiations, and to which access is controlled. Areas where workers might exceed three-tenths of any of the annual dose limits given in paragraph 5.4.3 should be included in controlled areas.

4.5.3. The boundaries of controlled areas will depend on the operational situation and it will often be convenient to use existing structural boundaries.

4.5.4. (1) The employer, with the advice of the radiation protection officer, should normally define controlled areas by warning signs, appropriately posted at the entrances and within the areas.

(2) These warning signs should display:

- (a) the basic radiation symbol shown in figure 1, which indicates the potential or actual presence of ionising radiations;
- (b) such additional inscriptions or symbols as are required to indicate in a manner understandable to all concerned the magnitude and particular nature of the exposure risk.

4.5.5. Access to controlled areas should be restricted to those workers assigned to work in these areas and to others whose access has been authorised by the appropriate level of management in consultation with the radiation protection officer.

4.5.6. It may be convenient to define areas where conditions are such that workers are unlikely to receive more than three-tenths of any of the annual dose limits given in paragraph 5.4.3, but might receive doses exceeding the values indicated in paragraph 5.4.5. These areas are called supervised areas.

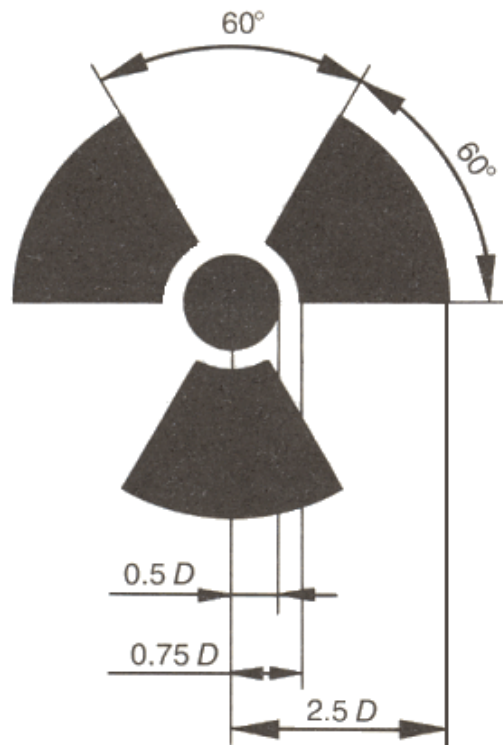


Figure 1. The symbol for ionising radiations<sup>1</sup>

4.5.7. The employer, with the advice of the radiation protection officer, may define supervised areas, which are normally marked with the basic radiation symbol shown in figure 1 and any additional information as appropriate indicating the sources of radiations.

4.5.8. The access of radiation workers to supervised areas should be subject to local operating instructions provided for by the department head in consultation with the radiation protection officer.

4.5.9. It should be noted that in general there is no exact parallel between the classification of areas and the classification of workers in respect of their working conditions, because the classification of areas normally does not take into account the time spent by the workers in the area during the course of the year and because conditions are rarely uniform throughout an area.

#### 4.6. Subclassification of areas within controlled areas and posting requirements

4.6.1. Within controlled areas it is often necessary to define regions where compliance with relevant limits can be achieved only by limiting the time spent by the worker in the region or by using special protective clothing or other protective devices.

<sup>1</sup> ISO 361-1975 is reproduced with the permission of the International Organization for Standardization (ISO), 1 rue de Varembé, 1211 Geneva 20, Switzerland.

## **Radiation protection of workers (ionising radiations)**

4.6.2. For the purposes of such special controls as may be necessary, employers should identify areas of high radiation levels, high airborne contamination or high surface contamination.

### **4.7. Requirements of controlled and supervised areas**

4.7.1. The employer should ensure, in consultation with the radiation protection officer, that:

- (a)* access to established controlled areas is adequately controlled;
- (b)* the appropriate radiation surveillance is carried out;
- (c)* the working procedures and instructions appropriate to the radiation risk are available, are updated as necessary and are adhered to by all concerned;
- (d)* the appropriate display signs, inscriptions or information indicating the sources and levels of radiations are properly posted;
- (e)* the appropriate radiation-measuring instruments are provided, and are regularly maintained and calibrated;
- (f)* safety features such as interlocks and filters are checked by qualified experts.



## 5. Limitation of radiation exposure (normal conditions)

### 5.1. Dose limitation system

5.1.1. During normal operating conditions, the exposure from sources or practices should be restricted by the application of the dose limitation system which includes justification of the practice, optimisation of radiation protection and establishment of the annual dose equivalent limits.

5.1.2. (1) Once the competent authority has authorised the introduction of a practice involving exposure to ionising radiations, the subsequent design, use and operation should be optimised from the point of view of radiation protection.

(2) The optimisation of radiation protection should be carried out taking into account the exposure of both workers and the public. If the choice of alternative safety options used for the protection of workers does not affect the exposure of the public to an appreciable extent, then optimisation of protection of workers could be carried out independently.

### 5.2. Optimisation of radiation protection through design

5.2.1. The optimisation of radiation protection should be implemented from the very start at the planning, design and construction stages, as a part of the licensing requirements as appropriate.

5.2.2. The process of optimisation should be appropriate to the specific risks of the installation, and thus may be simple or complex, depending on the extent of the risks involved. It should specifically take into account any potential impacts of design choices on the non-radiological risks present in the installation.

5.2.3. When applicable, optimisation should be based on a quantitative approach using any decision-making tools appropriate to the situation.<sup>1</sup>

5.2.4. The competent authority, in the event of differential cost-benefit analysis being chosen as an input in the decision-making process to determine the optimum radiation protection level, should recommend and agree on the monetary value or values attributed to the unit collective dose.

5.2.5. Quantitative optimisation is appropriate at the design stage, involving protection parameters such as thickness of shielding, ventilation flow rate and containment of radiation sources.

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<sup>1</sup> IAEA/ILO/NEA(OECD)/WHO: *Basic safety standards for radiation protection, 1982 edition*, op. cit., incorporating the ICRP recommendations (ICRP: "Recommendations of the International Commission on Radiological Protection", Publication No. 26, in *Annals of the ICRP* (Oxford, Pergamon Press), Vol. 1, No. 3, 1977), recommends the method of differential cost-benefit analysis. However, other decision-aiding methods are by no means excluded, as indicated in ICRP: "Cost-benefit analysis in the optimization of radiation protection", Publication No. 37, in *Annals of the ICRP*, Vol. 10, No. 2/3, 1983. The aggregative methods are the most commonly used. These are based on utility functions, where the cost-benefit analysis is a special case. Other methods include multi-criteria methods and may also include simple and qualitative approaches as appropriate.

## Radiation protection of workers (ionising radiations)

### 5.3. Optimisation of radiation protection under normal conditions

5.3.1. Adherence to good radiation protection practice is an important aspect of reducing exposure of workers and therefore a major step towards achieving optimum radiation protection.

5.3.2. The employer and the workers as appropriate are responsible for ensuring the optimisation of protection. The radiation surveillance and health surveillance services, and in particular the radiation protection officer, should discharge their functions as required by the employer.

5.3.3. Some operations, for example the management of effluents, lead to radiation in the general environment as well as the working environment. In such cases optimization should take account of exposures of both workers and the general public.

5.3.4. The employer, in consultation with the radiation protection officer, should for the purpose of optimisation:

- (a) structure the administrative organisation in a manner to ensure that the size of the workforce and its competence is consistent with optimisation requirements and the work being carried out;
- (b) organise and maintain an effective monitoring programme by selecting properly qualified and experienced personnel, with due regard to their number, and by providing suitable radiation protection equipment and ensuring its proper use and maintenance;
- (c) make provisions for adherence to the radiation protection rules and working instructions by means of appropriate supervision;
- (d) arrange for an effective training programme, including periodic retraining as appropriate, for different groups of workers including the radiation protection personnel;
- (e) ensure that the quality assurance programme is being carried out;
- (f) fulfil any other requirements to achieve the optimum choice amongst alternative operational procedures.<sup>1</sup>

### 5.4. Primary dose limits

#### General

5.4.1. The limits for the control of stochastic effects apply to the sum of the effective dose equivalents resulting from external exposure during one year, and the

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<sup>1</sup> In operational practice the optimisation decisions are largely qualitative. However, certain operations at an installation could, at least in part, be subject to quantitative optimisation procedures. Such operations include in-service inspection, and maintenance or repair operations. There are many and diverse parameters capable of influencing exposure to radiations that could be quantified for optimising the planned operation, but the experience is limited. However, there are several practical cases where quantitative values can be assessed approximately, and this is often sufficient for operational radiation protection purposes.

committed effective dose equivalents resulting from the intake of radionuclides during that year.

5.4.2. The limits for the control of non-stochastic effects apply to the sum of the dose equivalents to organs or tissues resulting from external exposure over one year, and the committed dose equivalents resulting from the intake of radionuclides during that year.

#### Primary dose limits for workers engaged in radiation work<sup>1</sup>

5.4.3. (1) Primary dose limits are individual-related values that apply to the annual doses received by workers from radiation sources related to work. These are as follows:

- (a) limit for the annual effective dose equivalent – 50 mSv;
- (b) limit for the annual dose equivalent in any organ or tissue (except lens of the eye) – 500 mSv;
- (c) limit for the annual dose equivalent in the lens of the eye – 150 mSv.

(2) The dose equivalents indicated above are the mean dose equivalent over the organ or tissue. In the case of skin, the dose equivalent resulting from skin contamination is averaged over 100 cm<sup>2</sup>, but if the contamination is very uneven, and is suspected to arise from an unplanned exposure, the dose equivalent should be averaged over 1 cm<sup>2</sup>. In the case of external exposure of the skin, the dose equivalent recorded by one or a few dosimeters is deemed to represent the dose to the skin. The effective dose equivalent is the quantity defined in the glossary at the end of this code.

5.4.4. The employer should make provisions to ensure that a pregnant woman does not work under Working Condition A. Recent information showing that there is a risk of inducing mental retardation confined to a limited period of pregnancy makes it necessary that no substantial irregularities to the dose rate occur for pregnant women working under Working Condition B.

#### Primary dose limits for workers not engaged in radiation work

5.4.5. The employer has the same obligations towards workers not engaged in radiation work, as far as restricting their radiation exposure is concerned, as if they were members of the public with respect to sources or practices under his control. The dose limits should be those applied to individual members of the public.<sup>2</sup>

### 5.5. Secondary limits for workers engaged in radiation work

5.5.1. In the case of internal exposure, secondary limits are expressed in terms

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<sup>1</sup> Specific provisions applying to workers under 18 years as well as to students, apprentices and trainees are given in section 4.1.

<sup>2</sup> The annual effective dose equivalent limit for members of the public is 1 mSv. However, it is permissible to use a subsidiary dose limit of 5 mSv in a year for some years, provided that the average annual dose equivalent over a lifetime does not exceed the principal limit of 1 mSv in a year. The annual dose equivalent limit for both the skin and the lens of the eye is 50 mSv (ICRP statement, Paris, 1985).

## Radiation protection of workers (ionising radiations)

of annual limits on intake (ALI).<sup>1</sup>

5.5.2. In the case of external exposure, compliance with the dose limits could be demonstrated if the value of the quantity<sup>2</sup> "individual dose equivalent penetrating  $H_p$  (10)" is less than or equal to 50 mSv and the value of the quantity "individual dose equivalent superficial  $H_s$  (0.07)" is less than or equal to 500 mSv.

## 5.6. Derived limits for workers engaged in radiation work

5.6.1. It may be convenient for operational reasons to use derived limits which are related to the primary limits by a defined model, so that if derived limits are observed it is likely that primary limits will be respected at the same time. The derived air concentration (DAC) can be used as appropriate by the employer as a value to demonstrate that the exposure of workers to fractions of derived concentration assures compliance with the dose limits.

5.6.2. When the employer chooses to use DAC to demonstrate compliance with the dose limits, the DAC values may be adjusted to reflect actual parametric values if the employer can justify the adjustment with a suitable data base relating, for example, to the particle size of aerosol inhaled.

## 5.7. Authorised and operational limits

5.7.1. (1) The competent authority may specify various authorised limits for various quantities relating to individual workers, sources of radiation or the environment.

(2) Such authorised limits take precedence over primary or derived limits and should be specified in the licence or by other appropriate means.

(3) They should be lower than the primary limits or derived limits.

5.7.2. (1) Authorised limits referred to in paragraph 5.7.1 may include, in addition to authorised dose limits, limits on quantities such as dose rates for different operating conditions within controlled and supervised areas and dose rates for radiation leakage from sealed or X-ray sources.

(2) Authorised limits may also be laid down to limit the quantity of radioactive substance used in a specified sealed or unsealed source or to limit the quantity of radioactive material in a specified workplace, store or container.

5.7.3. The employer, in consultation with the radiation protection officer, may, to ensure compliance with the authorised limits, lay down operational limits which are lower than the authorised limits.<sup>3</sup>

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<sup>1</sup> The values of ALI are given in Annex III of IAEA/ILO/NEA(OECD)/WHO: *Basic safety standards for radiation protection, 1982 edition*, op. cit.

<sup>2</sup> These quantities are described in recommendations of the International Commission on Radiation Units and Measurements (ICRU) given in ICRU: *Determination of dose equivalents resulting from external radiation sources*, Report No. 39 (Bethesda, Maryland, 1985).

<sup>3</sup> When a limit is expressed as an average over a certain period of time, it is understood that the actual value of the limited quantity over shorter periods of time may show considerable fluctuations.

## 5.8. Planned special exposure

5.8.1. The employer may authorise a worker aged 18 or over engaged in radiation work, and the worker may accept, to receive doses in excess of the limits specified in paragraph 5.4.3 subject to the provisions listed in paragraphs 5.8.2 to 5.8.8.

5.8.2. The dose equivalents or the committed dose equivalents incurred in the course of planned special exposures should not exceed twice the relevant annual limit specified in paragraph 5.4.3 in any one case and five times this limit over a lifetime.

5.8.3. The employer may authorise a planned special exposure only in an exceptional situation, when alternatives not involving such exposure cannot be used. The authorisation should be in writing.

5.8.4. The work organisation and radiation protection arrangements should be established in consultation with the workers' representatives.

5.8.5. The employer should ensure that the workers concerned are informed of the estimated doses and special conditions that might be involved in performing the tasks, and that they are consulted about the planned operation and informed of the potential occupational hazards.

5.8.6. Workers should be instructed in the measures to be taken to keep the doses and risks as low as reasonably achievable.

5.8.7. The employer should ensure that planned special exposure should not be authorised for a worker who has previously received abnormal exposures resulting in dose equivalents in excess of five times the relevant annual limit. The employer should ascertain from the approved medical practitioner whether the worker maintains his aptitude for the type of work involved.

5.8.8. The employer should report to the worker, to the approved medical practitioner and to the competent authority the dose equivalents or the committed dose equivalents resulting from planned special exposure.

5.8.9. Planned special exposures for operations involving an inhalation risk of radioactive substances should be avoided, as individual protective measures could effectively reduce the need for such exposures.

5.8.10. The dose equivalents or the committed dose equivalents resulting from planned special exposures should be recorded together with those resulting from usual exposures, but any excess over the limits specified in paragraph 5.4.3 for workers engaged in radiation work should not in itself constitute a reason for excluding a worker from his usual occupation.

## 5.9. Reference levels

5.9.1. For the purpose of radiation protection, the employer should apply reference levels as defined by the competent authority as follows:

(a) recording level: a level defined by the competent authority for dose equivalent, or

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effective dose equivalent or intake above which the information is of sufficient interest from a radiation protection point of view to be worth recording or keeping;

- (b) investigation levels: levels defined as values of dose equivalents or effective dose equivalent or intakes above which the results are considered sufficiently important to justify further investigations;
- (c) intervention levels: levels usually specified for use in abnormal situations. Such a level is specified in advance by a competent authority or the employer of the installation, so that if the value of a quantity does not exceed or is not predicted to exceed the intervention level then it is highly improbable that intervention will be warranted.

5.9.2. The employer may for operational convenience establish a reference level for any quantity used in radiation protection, whether or not there is a limit for the quantity.

5.9.3. The level of three-tenths of the dose limits for individual workers aged 18 and over is used as a reference level for administrative classification of conditions of work.

## **6. Limitation of radiation exposure (abnormal conditions)**

### **6.1. General**

6.1.1. The employer should draw up a plan for emergencies resulting from abnormal conditions on site as part of the overall plan for handling emergencies which might arise at the installation, taking due account of the accident analyses made in the safety analysis reports.

6.1.2. The employer should establish the appropriate lines of communication and arrangements for co-operation with all bodies which have actions to perform, such as local authorities (police, fire brigades, local hospitals) and national authorities.

6.1.3. The emergency plan should provide the means to demonstrate that the employer and his staff, particularly the radiation protection officer, are prepared to deal with any accident situation that may occur within the premises and that the necessary resources in terms of equipment and manpower are available, at least for the implementation of the immediate necessary steps. They should also know where and how to obtain additional assistance.

6.1.4. The employer should notify the specified authorities, in accordance with a pre-arranged system, of all accidents and emergency situations.

### **6.2. Procedures in case of emergency situations**

6.2.1. The employer, the radiation and health surveillance personnel and other safety personnel should prepare in advance, taking into account the potential for radiological hazards, a set of procedures for emergency situations including, as appropriate:

- (a) procedures for becoming aware of the existence of an accident, assessing the situation and taking the necessary steps based on information from special surveillance and monitoring data, predictions of outcome of exposures and an evaluation of the available countermeasures;
- (b) notification to ambulance and fire-fighting services and to rescue and decontamination teams concerning arrangements for the transport of injured persons, the issuing of appropriate warnings at the correct time, etc.;
- (c) the provision and periodic testing of an effective communication system, as well as procedures to notify all persons, services and organisations that an emergency situation exists, as appropriate to the real situation;
- (d) procedures to check that all personnel are accounted for, from the accident area to the pre-arranged assembly points;
- (e) procedures for initial rescue work and controlled re-entry into the affected area by those responsible for forestalling damage, and control measures to limit the extent of the incident on site;
- (f) procedures to carry out radiation surveys which give a rapid indication of the site radiological conditions and hazard areas;

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(g) procedures to set up an emergency centre for control and co-ordination of all aspects of the emergency situation.

6.2.2. The employer, the radiation and health surveillance personnel and all workers should, in addition to their normal duties, have an emergency duty to perform. These duties should be allocated according to a person's ability and experience in first aid, fire fighting, damage control including decontamination, or radiation monitoring.

6.2.3. The employer should test the organisation and planning of the emergency procedures and the training involved therein, by holding periodic well-planned drills which concentrate on the potential problem of a specific installation.

6.2.4. The employer should include in his emergency plan arrangements for medical assistance as appropriate, in the event of serious injuries caused by external or internal irradiation.<sup>1</sup>

## **6.3. Implementation of the emergency plan**

6.3.1. (1) The employer should make the necessary arrangements and identify the individual or individuals in line management with responsibility for implementing the necessary action and applying the appropriate countermeasures. These countermeasures have the purpose of regaining control of the abnormal situation, restricting the exposure of individuals as far as is reasonably achievable, minimising the consequences of unavoidable exposures, providing immediate medical aid to individuals and taking the first steps to reestablish normal conditions.

(2) The application for that purpose of the preset intervention levels defined in the emergency plan should be carried out with flexibility to allow adaptation to the real emergency situation, since this will generally differ from the reference accident situations in the safety analysis report.<sup>2</sup>

6.3.2. (1) Once the initial event has been brought under control, the remaining remedial work should be carried out while maintaining compliance with the dose equivalent limits.

(2) Exceptionally, there may be situations which require consideration of the appropriateness of authorising a planned special exposure for a limited number of individuals to carry out various essential operations, leaving the remainder to be done in compliance with the dose equivalent limits.

6.3.3. (1) Should emergency operations require that some workers incur

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<sup>1</sup> International assistance includes that provided by the IAEA through its Radiation Emergency Assistance Procedure, by the WHO through its system of collaborating centres on human radiation pathology, and by various States via regional or inter-country agreements on mutual assistance in the event of radiation accidents.

<sup>2</sup> The intervention levels are preset in such a way that, if a value of a quantity does not exceed or is predicted not to exceed the intervention level, it is highly improbable that the specified intervention will be required. Intervention levels expressed in terms of dose equivalent or intake and approved by the competent authority have come to be known as "emergency reference levels". Usually they are expressed as a range rather than a simple value to allow flexibility of application, as explained earlier in the text. It is helpful in practice to provide derived intervention reference levels applicable to the results of the measurements forming part of the special monitoring programme (see subparagraph 7.2.3 (c)).



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exposures in excess of the limits applicable to planned special exposures (see section 5.8), such emergency exposures may be considered as justifiable only when, for instance, it is urgent to rescue injured or trapped individuals, prevent injuries or avoid a substantial increase in the scale of the accident, including the rescue of items of high material value.

(2) In any case, these workers should be volunteers and should have received information about the risks involved in exposures substantially above the limits, and about appropriate rescue procedures.

6.3.4. The employer should make arrangements for the following to be available:

- (a) facilities located within the site for the decontamination of personnel, equipment and areas;
- (b) individual dosimeters, suitable protective clothing and respiratory protective equipment as appropriate to the situation for all persons carrying out protective actions;
- (c) sufficient quantities of various protective equipment, readily available to meet at least the minimum requirements foreseen in the emergency plan;
- (d) high-range radiation monitoring instruments, including dose rate instruments with or without an audible warning signal and battery-operated air samplers; furthermore, in selected areas, the radiation surveillance service should pre-install fixed monitoring instruments with high-level detection capabilities for rapid assessments of an emergency situation and follow-up of its evolution.

6.3.5. The employer should, with the advice of the radiation protection officer, make arrangements for:

- (a) maintaining the capability for sampling and analysing aerosols and leaking liquids, as might arise in accident conditions;
- (b) periodically testing and inspecting all equipment for emergency situations to ensure that the equipment is available and functions properly when needed.

6.3.6. (1) The physician in charge of health surveillance should have available, in case of radiation accident situations, adequate medical facilities and staff for the administration of first aid<sup>1</sup> and for carrying out external decontamination as appropriate. Life-saving measures should take precedence.

(2) The adequacy of such facilities should be reviewed regularly.

6.3.7. The employer should, with the advice of the physician in charge of

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<sup>1</sup> For the treatment and organisation of handling emergency overexposed workers, reference should be made to IAEA/WHO/ILO: *Manual on early medical treatment of possible radiation injury*, Safety Series No. 47 (Vienna, IAEA, 1978), and ICRP: "The principles and general procedures for handling emergency and accidental exposures of workers", Publication No. 28, in *Annals of the ICRP*, Vol. 2, No. 1, 1978.

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health surveillance and of the other services concerned, ensure, by appropriate administrative arrangements with suitably located hospitals specialising in the treatment of radiation injuries,<sup>1</sup> that workers are admitted when required with the least possible delay.

## 7. The radiation protection programme

### 7.1. General

7.1.1. A radiation protection programme should include the surveillance and monitoring of workers engaged in radiation work, the monitoring of the work area, the ergonomic study of the radiation protection provisions, the assessment of working methods with respect to health and safety, the establishment of contaminated areas, the continued assessment of protective measures, the classification of workers engaged in radiation work according to conditions of work, the provision of advice on decontamination procedures, and any other appropriate measures.

7.1.2. The radiation protection programme should be reviewed periodically in the light of experience, and also in the event of any new installations or practices or of any major modifications made to installations or practices, to ensure that it may continue to meet its objectives.

7.1.3. An integral part of any radiation protection programme should be a quality assurance programme aimed at ensuring that equipment and instruments function correctly, that procedures are properly established and implemented, that analyses are correctly performed, that errors are limited, that records are correctly and promptly maintained, that the required accuracy of measurements is maintained and that systematic errors do not arise, and that personnel are properly trained.

7.1.4. Radiation surveillance and health surveillance should be provided in accordance with the provisions listed in sections 7.2 and 7.3 respectively by appropriate radiation surveillance and health surveillance personnel or services.

7.1.5. The functions, organisation and conditions of operation of services entrusted with the surveillance of installations or practices where radiation sources are used or radio-active materials are handled should conform to the principles laid down in the Occupational Health Services Convention, 1985 (No. 161), and Recommendation, 1985 (No. 171).

7.1.6. (1) The detailed organisational arrangements needed to ensure adequate radiation protection in a specific installation depend on many factors, including the size of the installation or practice being carried out and the magnitude of the radiation risk involved.

(2) The organisation should be adequate and appropriate to the occupational risks of the installation, taking into account in particular:

- (a) the amount and nature of the radioactive materials being used or handled and whether they are in a sealed or a non-sealed form, and the type of radiation-producing apparatus such as X-ray equipment or accelerators;
- (b) the extent of the use of the source and the manner in which it is used;
- (c) the qualifications and competence of the operating personnel;
- (d) the installation in which the source is used;

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- (e) the expected maximum workload of the source, the type of work being carried out, e.g. open-beam or closed-beam work; and
- (f) the location and number of persons that will be working with, or are in the general vicinity of, the source.

7.1.7. In workplaces where work with ionising radiations is carried out and in which pregnant women are employed, the employer should ensure compliance with the provisions of paragraph 5.4.4. The employer, in co-operation with the approved medical officer if appropriate, should inform the women workers of:

- (a) the hazard to the foetus and of any restrictions placed by the competent authority on the employment of pregnant women in work causing exposure above specific levels of ionising radiation;
- (b) the need to inform him if, and as soon as, pregnancy needs to be taken into consideration so that the conditions of work may be determined.

7.1.8. (1) The radiation surveillance and health surveillance services should, as appropriate, be located within or near the place of employment, or should be organised in such a way as to ensure that their functions are carried out at the place of employment.

(2) They may be organised as a service or services within a single enterprise, or as a service or services common to a number of enterprises, as appropriate.

7.1.9. (1) The radiation surveillance and health surveillance services should have sufficient personnel with specialised training and experience in radiation protection, and in particular:

- (a) one or several radiation protection officers;
- (b) one or several qualified physicians or, whenever necessary, an approved medical practitioner;
- (c) the necessary supporting staff.

(2) The heads of the radiation surveillance and health surveillance services should have direct access to the employer.

7.1.10. The radiation surveillance and health surveillance services should collaborate<sup>1</sup> through predefined channels with:

- (a) those services which are concerned with the safety of workers in the enterprise;
- (b) the various units and departments of the enterprise in order to help them in formulating and implementing appropriate radiation protection programmes;
- (c) the workers' representatives, workers' safety representatives and the safety and health committee, when one exists.

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<sup>1</sup> It must be recognised that safety and security measures constitute, of necessity, an integral part of any radiation protection programme and that radiation protection measures should be followed and observed in conjunction with any preventive measures against conventional hazards.

## 7.2. Radiation surveillance

7.2.1. A programme of radiation surveillance should be established to determine the nature of precautions which must be taken to ensure compliance with the system of dose limitation presented in this code and to assess the effectiveness of precautions taken.

7.2.2. Records comprising the results of radiation surveillance as appropriate should be established and maintained (see section 7.5). Workers should have access to complete and accurate information on their radiation exposure records.

### Organisation of the radiation surveillance programme

7.2.3. A radiation surveillance programme should be organised, in general, according to the following elements:

- (a) routine monitoring, which is associated with continuing operations;
- (b) operational monitoring, intended to provide information about a particular operation; and
- (c) special monitoring, which is used in the case of an actual or suspected abnormal situation.

7.2.4. Any monitoring programme, either of workers or the workplace, should be adjusted as experience is gained, so that the type, frequency and extent of the measurements are periodically reviewed to ensure that protection efforts are optimised.

7.2.5. The measurements made in the course of monitoring programmes should be chosen so as to provide an adequate estimate of the quantities which need to be determined and to facilitate their interpretation.

7.2.6. All monitoring instruments should be tested for satisfactory performance and calibrated at appropriate intervals for the type of radiation for which they are used, and should be properly maintained and repaired.

7.2.7. The results of monitoring should be interpreted in terms of the relevant authorised limits or derived quantities, or reference levels as appropriate.

### Monitoring of the workplace

7.2.8. (1) Monitoring should be carried out at regular intervals in the radiation areas of the installation to demonstrate that the working environment is satisfactory for continued operations.

(2) Monitoring should include measurements of radiation fields and radioactive contamination in the air and on surfaces, as required, to demonstrate that the appropriate reference levels or authorised limits are not exceeded.

7.2.9. (1) Operational monitoring should be conducted for the purpose of checking a particular operation and should provide advice concerning decisions on the conduct of the operation.

(2) Operational monitoring should include measurements of radiation fields and, whenever a particular operation is likely to lead to a significant release of

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radioactive dust, vapour or gas, measurements of the air and surfaces within the working area.

(3) If there is any reason to believe that contamination may have spread from the working area, all suspected areas, including the area surrounding the facility, should be monitored.

7.2.10. Special monitoring of the work area should be carried out to cover either a situation in the working environment where insufficient information is available to achieve adequate control, or an operation that is being carried out in abnormal circumstances which may include accidents or suspected accidents.

### **Individual monitoring**

7.2.11. The exposure of workers engaged in radiation work A should be individually assessed. The workers should be subject to external radiation monitoring, internal monitoring or both, as appropriate.

7.2.12. In addition, workers who are not routinely monitored on an individual basis (Working Condition B), but who occasionally enter a radiation area, may require operational monitoring or special monitoring, as appropriate to the situation.

7.2.13. An individual dose assessment, and hence also individual monitoring, is not required for workers designated as working in Working Condition B. In some situations, an easily performed method of individual monitoring of those workers (e.g. for external photon irradiation or for exposure to tritium) may, however, usefully replace monitoring of the workplace or, when performed for a certain period, assist in confirming or reassessing the working conditions.

7.2.14. Special consideration should be given, at the beginning of a new work assignment involving unsealed radioactive material, to the appropriate monitoring for a worker who has previously had a significant intake of long-lived radioactive material.

7.2.15. The results of monitoring should be evaluated in terms of the quantities in which primary or secondary limits are expressed. When appropriate, the results could also be used to assess the collective dose.

7.2.16. The results of monitoring serve as a basis for assessing compliance with the requirements of the system of dose limitation and for the planning of future work.

7.2.17. Radiation doses should be reported in accordance with the requirements of the competent authority.

7.2.18. Temporary workers such as contractors, guest scientists, students and research fellows who may be engaged in radiation work should be monitored to the same standards as workers permanently engaged in radiation work.

7.2.19. Although the monitoring of visitors is not required, the use of simple external individual dosimeters is sometimes advisable, as are contamination checks, where appropriate.

7.2.20. Routine individual monitoring comprises regularly repeated or continuous measurements taken from individual workers. If the estimated annual dose equivalents or intakes are well below the dose limits given in paragraph 5.4.3, it would

be sufficient to assess the upper limits of the estimates rather than the actual values and to assess their importance using, for example, the investigation levels, bearing in mind that for the purposes of optimisation of radiation protection actual assessments rather than upper limits are needed.

7.2.21. Operational individual monitoring, for example by the provision of additional dosimeters, may significantly improve the monitoring programme, especially if devices using direct readings or alarm signals are provided. Operational monitoring is implemented only for a particular operation or a series of operations.

#### Special monitoring for accidental over-exposure

7.2.22. Where there are areas in which serious radiation hazards could arise in the event of an accident, plans should be made in advance about the monitoring programmes that would be required under emergency conditions.

7.2.23. The extent of planning and the provision of facilities for the evaluation of doses under conditions of over-exposure will depend on both the probability and the seriousness of the potential emergency situation.

### 7.3. Health surveillance of workers engaged in radiation work

7.3.1. The employer should provide health surveillance of workers engaged in radiation work and ensure that all assessments to protect the health of workers are carried out. Such health surveillance of workers engaged in radiation work should be based on the general principles of occupational health.<sup>1</sup>

7.3.2. Health surveillance should be established in order to

- (a) assess the health of the workers;
- (b) help ensure initial and continuing compatibility between the health of the workers and their work;
- (c) provide reference data useful in the case of accidental exposure or occupational disease.

7.3.3. (1) Health surveillance of workers engaged in radiation work should include appropriate medical surveillance carried out by a physician experienced in occupational and radiation health, who would be responsible for such surveillance in the light of the hazard involved and the type of work being carried out.

(2) The health surveillance of workers engaged in radiation work A should be carried out by an approved medical practitioner.

7.3.4. Health surveillance for normal conditions of work should include:

- (a) health assessment appropriate to the specific tasks to be performed, before the worker begins the assignment;
- (b) periodic health surveillance during the assignment;
- (c) special health surveillance when needed and as prescribed by the competent

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<sup>1</sup> Occupational Health Services Convention, 1985 (No. 161), and Recommendation, 1985 (No. 171).

## **Radiation protection of workers (ionising radiations)**

authority for workers engaged in radiation work A;

- (d) assessment when a pregnancy is reported;
- (e) other health assessments as required by the competent authority.<sup>1</sup>

7.3.5. (1) The health surveillance following an abnormal exposure should include special assessment when:

- (a) the results of radiological surveillance indicate that the individual has received radiation dose equivalents in excess of twice the relevant dose limits;
- (b) before an individual is to return to radiation work, having been restricted from work on medical grounds following a radiation accident.

(2) Any decision based on a special assessment of this nature should be communicated to the employer.

7.3.6. Each worker should be informed in an adequate and appropriate manner of the results of the health examinations he has undergone and of the assessment of his health.

7.3.7. The conclusions with respect to a worker's medical fitness for a particular radiation work assignment should be communicated in writing to both the worker and the employer. These conclusions should contain no information of a medical nature; they might, as appropriate, indicate fitness for the proposed assignment or specify the kinds of jobs and the conditions of work which are medically contraindicated, either temporarily or permanently.

7.3.8. Records of the results of health surveillance should be kept according to the provisions given in section 7.5.

## **7.4. Control of radiation exposure of workers**

### **General requirements**

7.4.1. (1) The employer should ensure that, as far as practicable, the arrangements for restricting occupational exposure should be those applied to the source of radiation and to features of the workplace.

(2) Intrinsic safety in the workplace should take priority over the individual protection of workers.

(3) The use of personal protective equipment should in general be supplementary to the more fundamental provisions.

7.4.2. The radiation protection programme should provide for the requirements of:

- (a) design features;
- (b) operational procedures; and
- (c) protective safety devices and equipment.

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<sup>1</sup> Where occupationally related diseases might occur, provisions should be made for appropriate medical examinations, biological or other tests, or investigations to continue to be available to the workers after cessation of the assignment.



## The radiation protection programme

7.4.3. The radiation protection measures should be designed, planned and implemented with the advice of the radiation protection officer and of the physician in charge of health surveillance, taking into account national regulations and the requirements of this code.

7.4.4. The radiation protection programme should include the following:

- (a) advising on proposed modifications in work processes or in conditions of work which are likely to have an effect on the health or safety of the workers;
- (b) providing for the elaboration of radiation protection rules and procedures suitable for the particular installation, and participating in the instruction of workers;
- (c) carrying out inspections on a routine basis to verify compliance with the provisions of this code, the relevant regulations and the requirements of the safety analysis report;
- (d) advising the person in charge of installations on any remedial action that needs to be taken in the event of non-compliance;
- (e) providing assistance and advice on methods of decontaminating work areas, equipment, protective devices, clothing and skin, and ensuring, by monitoring before work is resumed, that the residual levels of contamination are below the prescribed limits.

7.4.5. When defects occur which affect or could affect the control of radiation exposure of workers, measures should immediately be taken to ensure the adequate control of radiation exposure and to remedy the defect.

### Design features requirements

7.4.6. Buildings, plant and equipment (including protective equipment, radiation-measuring equipment, visual or audible alarm signals, public address systems, etc.) should be appropriate to their intended use, taking into account the potential for radiological hazards. They should also comply with the relevant regulations and with the quality assurance requirements as laid down in the licence, if any.

7.4.7. Special consideration should be given to the choice of fire-proof construction for buildings, particularly those where radioactive substances are being stored, used or handled.

7.4.8. (1) Floors in buildings should present no risk of tripping, should have even and non-slip surfaces and should be designed and constructed to support the weight of the necessary shielding against X-ray, gamma-emitting or neutron sources.

(2) Working space should whenever practicable be of sufficient dimensions to enable the workers to carry out their jobs in an unhampered way.

(3) Where a radioactive contamination hazard exists, floors, working surfaces and ceilings should be designed for easy cleaning. The walls and the ceilings should be covered with a washable surface. The junctions of floors and walls should be sealed and rounded off to facilitate the cleaning of workplace floors.

7.4.9. The layout, dimensions and execution of emergency escape routes should be related to the operations carried out, to the nature of hazards and to the number of persons in the installation. Emergency escape routes should be marked as such and

## **Radiation protection of workers (ionising radiations)**

should lead by the shortest possible route, taking into account potential radiation exposure, to a safe area.

7.4.10. (1) The general lighting should give adequate and uniform levels of illumination in all workplaces consistent with the nature of the work being performed.

(2) Emergency lighting should be provided where a radiation accident hazard might occur in the event of failure of the general lighting.

7.4.11. Emergency power sources of the required reliability should be available, in case of power failures, to sustain vital equipment and instruments as well as to ensure the adequate operation of the ventilation systems.

7.4.12. (1) Workers should have an adequate supply of wholesome respirable air, with due allowance being made for the working process involved.

(2) Where there is a risk of internal exposure due to inhalation of airborne contamination, a ventilation system should be provided so as to keep this risk as low as reasonably achievable. The design of the ventilation system may be based on either dilution or dynamic containment principles, as appropriate to the circumstances.

(3) In various types of work, such as the underground mining of uranium ore, ventilation should provide sufficient fresh air to each working area in order to minimise exposure to dust and radon and thoron daughters.

7.4.13. Any significant fault in the ventilation system should be brought to the attention of the person responsible for the operation of the system and of the workers dependent on it, if necessary by means of an automatic warning device.

7.4.14. (1) In work areas where a significant emission of radioactive gases, vapours, fumes or mists cannot be prevented, these should be collected by exhaust ventilation at the point of emission and filtered by the appropriate type of filter.

(2) Where there is a risk that significant radioactive contamination may spread, the ventilation system should be operated continuously and no significant changes should be made unless they become necessary in the case of an emergency.

7.4.15. The control of external irradiation of workers should be achieved with due consideration to many factors, in particular the following:

- (a) the characteristics of the source, e.g. its activity;
- (b) the distance between the source and the exposed individuals;
- (c) the exposure time; and
- (d) the shielding.

7.4.16. The main control parameters for external irradiation which should be subjected to optimisation of radiation protection are the shielding thickness and the working practice procedures.

7.4.17. The adequate shielding of radiation sources should be used to produce intrinsically safe conditions in the workplace, taking into account that:

- (a) shielding is not normally required for alpha radiation;
- (b) shielding should be provided for beta, gamma, X-ray and neutron radiation. In the case of beta radiation of higher energy and of neutron radiation, additional precautions may be needed against photon radiation caused by bremsstrahlung or

as a result of all kinds of interactions of neutrons with matter, respectively.

7.4.18. In designing the shielding, the following should be considered:

- (a) the irradiation of all individuals from other sources, including irradiation from internal sources;
- (b) the maximum leakage radiation from the source housing and the maximum stray radiation;
- (c) the occupancy factor; however, this varies greatly depending upon different installations and different usages and should, if employed to relax the shielding requirements, be used after careful consideration and in compliance with national regulations.

7.4.19. Shielding provisions require that:

- (a) shielding material and its use conform with the quality assurance requirements; concrete shielding material should be homogeneous and of the approved composition and density, as specified; lead should be used in a manner to prevent creep under its own weight and should be covered to prevent corrosion;
- (b) shielding is not defective at places where tubes or electrical wiring penetrate the shield or at joints and similar positions; maze arrangements should be considered whenever practicable, or the overlapping of shields at the edges;
- (c) diaphragms, cones or adjustable collimators should be used to limit the useful beam.

7.4.20. The design requirements for the control of internal contamination of workers should be based on the containment of the source by one or more barriers and the limitation of the spread of contamination by appropriate ventilation and air-cleaning systems, to comply with the requirements given in paragraphs 7.4.12 to 7.4.14.

#### Operational procedures requirements

7.4.21. The working procedures and methods for manipulating radiation sources or radioactive substances, including storage and disposal, should be conducted in a manner consistent with keeping doses of workers as low as reasonably achievable within the constraint of the individual dose limits or the individual authorised dose limit, as the case may be.

7.4.22. Operational measures for the control of exposure include requirements such as:

- (a) the proper layout of working areas, including demarcation of controlled areas and of high radiation and contamination areas;
- (b) the enforcement of the appropriate radiation protection rules and procedures for the workplace in question;
- (c) the monitoring of individuals and workplaces;
- (d) work planning; and
- (e) the appropriate training of personnel.

7.4.23. Since the external exposure of individuals can usually be more readily measured and kept under control than internal exposure, the control of workers'

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exposure is considerably simplified and improved if measures are taken to keep internal exposure to a negligible level. However, the latter should not result in an increase in external exposure and thereby reduce the advantages obtained.

7.4.24. Radiation sources other than those exempted should be properly packaged and labelled to permit identification of the hazards involved. The packaging and transport of radioactive material outside the plant should conform to *Regulations for the safe transport of radioactive material*, published by the IAEA.<sup>1</sup>

### Protective safety devices and equipment<sup>2</sup>

7.4.25. All protective safety devices and equipment should be suitable for the purpose for which they are intended, and should as far as possible be convenient to use.

7.4.26. (1) Such devices should be examined by a competent person to ensure that they are in good condition and operating satisfactorily.

(2) An examination of this nature should be conducted before the devices and equipment are put into use, whenever changes are made in procedures, equipment or shielding, and periodically as appropriate.

(3) Any defects found should be remedied at the appropriate time.

(4) The results of these examinations should be recorded.

## 7.5. Record-keeping requirements

### General

7.5.1. (1) Records should be kept in a form and in a manner approved by the competent authority to enable the employer to demonstrate that the radiation protection programme has been effectively carried out.

(2) Due care and attention should be given to the maintenance of the confidentiality of the records, as appropriate.

7.5.2. Consideration should be given to keeping records up to date to a reasonable extent and, when appropriate, in a machine-readable form. They should be preserved in a safe manner.

7.5.3. Records should be readily retrievable to facilitate, in particular:

- (a) the obtaining of information on doses and exposure conditions concerning workers who undertake work in controlled areas in different installations under the responsibility of different employers, to ensure compliance with the requirements laid down in subparagraphs 2.2.2 (1) to (4);
- (b) the follow-up of workers' health after termination of employment, and the preparation of epidemiological studies if required.

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<sup>1</sup> 1985 edition, Safety Series No. 6 (Vienna, 1985).

<sup>2</sup> The application of the provisions given in this code to specific situations require more detailed guidance, which may be found in specialised publications of the IAEA and the other international organisations concerned.

7.5.4. Records should be kept for such periods as may be specified by the competent authority for different record types, e.g. long term for individual doses and health records and radioactive waste-disposal records; medium term for incoming and outgoing shipments of radioactive materials; or short term for instrument calibration records.

7.5.5. Record keeping is needed for:

- (a) demonstrating the degree of compliance with the radiation protection regulations and the requirements as laid down in this code;
- (b) medical purposes;
- (c) the evaluation of dose trends;
- (d) the evaluation of collective doses;
- (e) epidemiological studies and evaluations of health effects.

#### Radiation surveillance records

7.5.6. A record-keeping system should be established and should include information on the monitoring programme and records on:

- (a) individual doses;
- (b) working environment radiation levels.

7.5.7. (1) The competent authority should define the values of recording levels for the dose equivalent, effective dose equivalent or intake above which the result of monitoring is of sufficient interest to be worth recording and keeping.

(2) Values below the recording level may be covered by the statement that they did not exceed the defined recording level and may be treated as zero for assessing the dose equivalent of an individual worker. However, records of such monitoring data might be required for research (e.g. epidemiological studies) or for assessing collective doses.

7.5.8. The results of individual monitoring for both external irradiation and internal contamination, as well as area monitoring, should be recorded.

7.5.9. Records on individual doses should register:

- (a) separate external and internal committed doses or intakes from which the effective dose equivalents may be calculated;
- (b) the total dose as specified in (a) for the current year for workers who might have been exposed while working for other employers;
- (c) all emergency and accidental doses and intakes, where identifiable; these should be recorded together and clearly distinguished from normal exposures.

7.5.10. Records of individual doses should be preserved during the lifetime of the person concerned, and in any case for at least 30 years after cessation of work involving exposure to radiations. Due care and attention should be given to the maintenance of confidentiality of these records, as required by the competent authority.

7.5.11. Records of working environment radiation levels should be kept as appropriate. Except where significant exposure of an individual is involved, records of survey meter readings are in general only of transitory interest (to be kept for a limited

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period only).

7.5.12. Access to data resulting from the radiological surveillance of the working environment should be ensured and their confidentiality maintained in accordance with the relevant provisions of the Occupational Health Services Recommendation, 1985 (No. 171).

7.5.13. The collective doses actually incurred in special operations or types of work may be recorded together with expected collective doses as assessed prior to the actions taken.

### Health records

7.5.14. Records of the results of health surveillance, including medical decisions, should be kept for every worker engaged in radiation work, in a form approved by the competent authority.

7.5.15. Such records should contain all relevant information concerning at least:

- (a) the nature of the work involving radiation exposure, types of radiation and the periods during which the radiation exposure was received;
- (b) the results of assessment of individual exposures;
- (c) the conclusions of medical examinations carried out.

7.5.16. (1) The health records should be kept and their confidentiality maintained in accordance with the relevant provisions of the Occupational Health Services Recommendation, 1985 (No. 171).

(2) Data on workers' health, together with the relevant results of assessment of individual exposures as requested by the physician in charge of health surveillance, should be recorded in personal confidential files. Where the files contain personal information covered by medical confidentiality, access to these files should be restricted to medical personnel. Personal data relating to health assessments may be communicated to others only with the informed consent of the worker concerned.

7.5.17. (1) Records should be kept in such a form as the competent authority may require.

(2) They should be preserved during the lifetime of the person concerned, and in any case for at least 30 years after cessation of work involving exposure to radiations or for such a period as the competent authority may specify.

### Other records

7.5.18. Additional documents may be kept in support of the radiation protection programme, such as:

- (a) the instrument calibration record;
- (b) the inventory of protective equipment;
- (c) the inventory of radioactive materials and radiation sources;
- (d) the radioactive shipment record;
- (e) over-exposures and emergency reports;
- (f) radiation protection training records;

- (g) the waste disposal record.

#### Retention of records

7.5.19. The employer should keep available for the competent authority, if prescribed by this authority, the following:

- (a) a summary of the workers' radiation exposures including the number of workers exposed, the level of their exposure and, when appropriate, the collective dose;
- (b) a summary of the type and quantity of radioactive substances or radiation sources used, including a summary of the results of measurements carried out at the workplace;
- (c) a summary of the preventive and protective measures taken to comply with the requirements of this code;
- (d) any other information or records related to the workers' health.

7.5.20. The competent authority should prescribe the circumstances (for example due to liquidation) in which an employer is relieved of his obligation to retain records. It should also prescribe how the records should then be retained.

## 8. Glossary of some of the terms used

*Annual dose equivalent limit:* The value of the annual dose equivalent that must not be exceeded, according to the ICRP system of dose limitation.<sup>1</sup>

*Annual limit on intake (ALI):* ALI is a secondary limit for the internal exposure of radiation workers. It is the smaller value of intake of a given radionuclide in a year by Reference Man<sup>2</sup> which would result in either a committed effective dose equivalent of 50 mSv or a committed dose equivalent in the lens of the eye of 150 mSv or in any other organ or tissue of 500 mSv.

*Approved medical practitioner:* A medical practitioner responsible for the health surveillance of occupationally exposed workers and whose capacity to act in this respect is recognised by the competent authority.

*Area, controlled:* An area where workers might receive doses in excess of three-tenths of the occupational dose equivalent limits for workers engaged in radiation work during the anticipated working period, and where appropriate controls (such as restricted access, individual assessment of dose and special health surveillance) are accordingly applied.

*Area, supervised:* An area where radiation levels are such that annual exposure is most unlikely to exceed three-tenths of the occupational dose equivalent limits but may exceed one-tenth of those limits, and where special forms of supervision (such as area monitoring) are accordingly applied.

*"As low as reasonably achievable":* Synonym for optimisation (see *Optimisation*).

*Becquerel, Bq:* The name of the unit of activity. The activity,  $A$ , of an amount of a radioactive nuclide in a particular energy state at a given time is the quotient of  $dN$  by  $dt$ , where  $dN$  is the expectation value of the number of spontaneous nuclear transitions from that energy state in the time interval  $dt$ :

$$A = \frac{dN}{dt} .$$

The SI unit of activity is  $s^{-1}$ . The special name of this unit is becquerel (Bq):

$$1 \text{ Bq} = 1 \text{ s}^{-1} .$$

The unit of activity previously used was the curie (Ci):

$$1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq} .$$

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<sup>1</sup> See ICRP: "Recommendations of the International Commission on Radiological Protection", op. cit.

<sup>2</sup> See ICRP: *Report of the Task Group on Reference Man*, Publication No. 23 (Oxford, Pergamon Press, 1975).



*Competent authority:* An authority designated or otherwise recognised by a government for specific purposes in connection with radiation protection or nuclear safety, or both.

*Contamination, radioactive:* The presence of a radioactive substance or substances in or on a material or in a place where that presence is undesirable.

*Decontamination:* The removal of radioactive contaminants with the objective of reducing the residual activity in or on materials and persons or in the environment.

*Dose:* A term denoting the quantity of radiation energy absorbed by a medium. For radiation protection purposes, there is a hierarchy of dose quantities. These include: absorbed dose,  $D$ ; dose equivalent,  $H$ ; effective dose equivalent,  $H_E$ ; committed effective dose equivalent,  $H_{E,50}$ ; and collective effective dose equivalent,  $S_E$ .

*Absorbed dose,  $D$ :* Exposure of tissues and organs to radiations result in energy deposition. The absorbed dose,  $D$ , is defined by:

$$D = \frac{d\bar{\epsilon}}{dm},$$

where  $d\bar{\epsilon}$  is the mean energy imparted by radiations to the matter in a volume element and  $dm$  is the mass in that volume element. The SI unit of absorbed dose is  $J \cdot kg^{-1}$ . The special name of this unit dose is gray, Gy:

$$1 \text{ Gy} = 1 J \cdot kg^{-1}.$$

The unit of absorbed dose previously used was the rad:

$$1 \text{ rad} = 10^{-2} \text{ Gy}.$$

It should be noted that equal absorbed doses resulting from different types of radiations do not result in the same health risk or health detriment because of many factors in addition to the absorbed energy at the place of interest. These include the energy transfer pattern within the system, which depends on the quality of radiation, the fractionation of the dose or the dose rate.

*Dose equivalent,  $H$ :* This is a quantity obtained by weighting the absorbed dose by a number of dimensionless factors. The weighted absorbed dose correlates better with the detriment. The dose equivalent,  $H$ , is the product of  $D$ ,  $Q$  and  $N$ , where  $D$  is the absorbed dose,  $Q$  is the quality factor and  $N$  is the product of all other modifying factors:<sup>1</sup>

$$H = DQN.$$

The SI unit for dose equivalent is  $J \cdot kg^{-1}$ . The special name of this unit is sievert, Sv:

$$1 \text{ Sv} = 1 J \cdot kg^{-1}.$$

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<sup>1</sup> At present the ICRP assigns a value 1 to the factor  $N$  for all irradiation conditions.

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The unit of dose equivalent previously used was the rem:

$$1 \text{ rem} = 10^{-2} \text{ Sv.}$$

The quality factor,  $Q$ , is defined as a function of linear energy transfer at the point of interest. However, the following approximations of the average  $Q$  for different incident radiations are acceptable:

	$\bar{Q}$
X-rays, gamma rays and electrons	1.0
Thermal neutrons*	4.6
Other neutrons*	20.0
Protons and single-charged particles	10.0
Alpha particles and multiple-charged particles of unknown energy	20.0

\*It is valid to use the old value, which is one-half of the one given, but the records should indicate which of the two values has been used.

*Effective dose equivalent,  $H_E$* : A quantity defined as:

$$H_E = \sum_T w_T H_T,$$

where  $H_T$  is the mean dose equivalent in the organ or tissue  $T$ , and  $w_T$  is a weighting factor specified in the table below.

Tissue	$w_T$	Tissue	$w_T$
Gonads	0.25	Thyroid	0.03
Breast	0.15	Bone surfaces	0.03
Red bone marrow	0.12	Remainder	0.30
Lung	0.12		

*Committed effective dose equivalent,  $H_{E,50}$* : This is the effective dose equivalent that will be accumulated by a worker over 50 years, representing the working life following an intake:

$$H_{E,50} = \int_{t_0}^{t_0+50} \dot{H}_E(t) dt,$$

where  $\dot{H}_E(t)$  is the effective dose equivalent rate at the time  $t_0$  and  $t_0$  is the time of intake.

*Collective effective dose equivalent,  $S_E$* : The collective effective dose equivalent,  $S_E$ , is given by the expression:

$$S_E = \int_0^{\infty} H_E P(H_E) dH_E,$$

where  $P(H_E)$  is the group spectrum of the working population in effective dose equivalents, the product  $P(H_E)dH_E$  being the number of individuals receiving an effective dose equivalent in the range  $H_E$  to  $H_E+dH_E$ . The unit of collective effective dose equivalent is mansievert (man.Sv).

*Exposure*: A term used in radiation protection both in a specifically defined quantitative sense and in a general sense. Exposure is used here in the general sense with the meaning of "irradiation of persons or materials". Exposure of persons to ionising radiations may be either:

- (a) *external exposure*: irradiation by sources outside the body; or
- (b) *internal exposure*: irradiation by sources inside the body.

The term occupational exposure refers to exposure of a worker received or committed during a period of work.

*Justification of a practice*: A term proposed by the ICRP to express the principle that no practice resulting in human exposure to radiation should be authorised by the relevant competent authorities unless its introduction produces a positive net benefit.

*Licence*: A licence is an official document which authorises a specified practice or set of practices, establishes requirements and conditions governing the performance of these practices, and possibly places time-limits on the validity of authorisations. A licence could be a specific licence associated with a particular radiation source, including instructions concerning use, storage and disposal as appropriate, or a general licence authorising the possession and use of certain radiation sources specified in the licence.

*Monitoring*: The measurement of irradiation or radioactivity for reasons related to the estimate or control of radiation exposure. The term includes the interpretation of the measurements.

*Non-stochastic effects*: These are biological radiation effects for which a threshold exists above which the severity varies with the dose. These effects include non-malignant skin injury, cataract of the lens of the eye, cell depression in the bone marrow and gonadal cell damage leading to impairment of fertility.

*Optimisation*, or keeping doses "as low as reasonably achievable", taking economic and social factors into account, means reducing doses to a point where further reductions involve more effort than the additional benefit they achieve.<sup>1</sup>

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<sup>1</sup> cf. ICRP: "Recommendations of the International Commission on Radiological Protection", op. cit.; idem: "Cost-benefit analysis in the optimization of radiation protection", op. cit.; IAEA/ILO/NEA(OECD)/WHO: *Basic safety standards in radiation protection, 1982 edition*, op. cit.

### **Radiation protection of workers (ionising radiations)**

*Radiation protection officer:* A technically competent person designated by the employer to survey the application of radiation protection regulations, standards and rules, and to provide advice on all relevant aspects of radiation protection.

*Radiation work:* Any work connected with exposure of workers to ionising radiations performed in premises containing the radiation sources giving rise to the exposure.

*Stochastic effects:* These are biological radiation effects whose severity is independent of dose and whose probability is assumed to be proportional to the dose without threshold at the low doses of interest in radiation protection. These effects include malignant diseases and hereditary diseases. The effects, when they occur to the individual exposed to radiation, are called somatic stochastic effects; when they occur in the offspring of irradiated parents, they are known as hereditary effects.

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