

# IAEA Safety Standards

for protecting people and the environment

## Radiation Safety in Industrial Radiography

Specific Safety Guide

No. SSG-11



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Under the terms of Article III of its Statute, the IAEA is authorized to establish or adopt standards of safety for protection of health and minimization of danger to life and property, and to provide for the application of these standards.

The publications by means of which the IAEA establishes standards are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety. The publication categories in the series are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides**.

Information on the IAEA's safety standards programme is available at the IAEA Internet site

<http://www-ns.iaea.org/standards/>

The site provides the texts in English of published and draft safety standards. The texts of safety standards issued in Arabic, Chinese, French, Russian and Spanish, the IAEA Safety Glossary and a status report for safety standards under development are also available. For further information, please contact the IAEA at PO Box 100, 1400 Vienna, Austria.

All users of IAEA safety standards are invited to inform the IAEA of experience in their use (e.g. as a basis for national regulations, for safety reviews and for training courses) for the purpose of ensuring that they continue to meet users' needs. Information may be provided via the IAEA Internet site or by post, as above, or by email to [Official.Mail@iaea.org](mailto:Official.Mail@iaea.org).

## OTHER SAFETY RELATED PUBLICATIONS

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Reports on safety and protection in nuclear activities are issued as **Safety Reports**, which provide practical examples and detailed methods that can be used in support of the safety standards.

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# RADIATION SAFETY IN INDUSTRIAL RADIOGRAPHY



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The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

IAEA SAFETY STANDARDS SERIES No. SSG-11

# RADIATION SAFETY IN INDUSTRIAL RADIOGRAPHY

SPECIFIC SAFETY GUIDE

INTERNATIONAL ATOMIC ENERGY AGENCY  
VIENNA, 2011

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## FOREWORD

**by Yukiya Amano**  
**Director General**

The IAEA's Statute authorizes the Agency to “establish or adopt... standards of safety for protection of health and minimization of danger to life and property” — standards that the IAEA must use in its own operations, and which States can apply by means of their regulatory provisions for nuclear and radiation safety. The IAEA does this in consultation with the competent organs of the United Nations and with the specialized agencies concerned. A comprehensive set of high quality standards under regular review is a key element of a stable and sustainable global safety regime, as is the IAEA's assistance in their application.

The IAEA commenced its safety standards programme in 1958. The emphasis placed on quality, fitness for purpose and continuous improvement has led to the widespread use of the IAEA standards throughout the world. The Safety Standards Series now includes unified Fundamental Safety Principles, which represent an international consensus on what must constitute a high level of protection and safety. With the strong support of the Commission on Safety Standards, the IAEA is working to promote the global acceptance and use of its standards.

Standards are only effective if they are properly applied in practice. The IAEA's safety services encompass design, siting and engineering safety, operational safety, radiation safety, safe transport of radioactive material and safe management of radioactive waste, as well as governmental organization, regulatory matters and safety culture in organizations. These safety services assist Member States in the application of the standards and enable valuable experience and insights to be shared.

Regulating safety is a national responsibility, and many States have decided to adopt the IAEA's standards for use in their national regulations. For parties to the various international safety conventions, IAEA standards provide a consistent, reliable means of ensuring the effective fulfilment of obligations under the conventions. The standards are also applied by regulatory bodies and operators around the world to enhance safety in nuclear power generation and in nuclear applications in medicine, industry, agriculture and research.

Safety is not an end in itself but a prerequisite for the purpose of the protection of people in all States and of the environment — now and in the future. The risks associated with ionizing radiation must be assessed and controlled without unduly limiting the contribution of nuclear energy to equitable and sustainable development. Governments, regulatory bodies and operators everywhere must ensure that nuclear material and radiation sources are used beneficially, safely and ethically. The IAEA safety standards are designed to facilitate this, and I encourage all Member States to make use of them.



# THE IAEA SAFETY STANDARDS

## BACKGROUND

Radioactivity is a natural phenomenon and natural sources of radiation are features of the environment. Radiation and radioactive substances have many beneficial applications, ranging from power generation to uses in medicine, industry and agriculture. The radiation risks to workers and the public and to the environment that may arise from these applications have to be assessed and, if necessary, controlled.

Activities such as the medical uses of radiation, the operation of nuclear installations, the production, transport and use of radioactive material, and the management of radioactive waste must therefore be subject to standards of safety.

Regulating safety is a national responsibility. However, radiation risks may transcend national borders, and international cooperation serves to promote and enhance safety globally by exchanging experience and by improving capabilities to control hazards, to prevent accidents, to respond to emergencies and to mitigate any harmful consequences.

States have an obligation of diligence and duty of care, and are expected to fulfil their national and international undertakings and obligations.

International safety standards provide support for States in meeting their obligations under general principles of international law, such as those relating to environmental protection. International safety standards also promote and assure confidence in safety and facilitate international commerce and trade.

A global nuclear safety regime is in place and is being continuously improved. IAEA safety standards, which support the implementation of binding international instruments and national safety infrastructures, are a cornerstone of this global regime. The IAEA safety standards constitute a useful tool for contracting parties to assess their performance under these international conventions.

## THE IAEA SAFETY STANDARDS

The status of the IAEA safety standards derives from the IAEA's Statute, which authorizes the IAEA to establish or adopt, in consultation and, where appropriate, in collaboration with the competent organs of the United Nations and with the specialized agencies concerned, standards of safety for protection

of health and minimization of danger to life and property, and to provide for their application.

With a view to ensuring the protection of people and the environment from harmful effects of ionizing radiation, the IAEA safety standards establish fundamental safety principles, requirements and measures to control the radiation exposure of people and the release of radioactive material to the environment, to restrict the likelihood of events that might lead to a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation, and to mitigate the consequences of such events if they were to occur. The standards apply to facilities and activities that give rise to radiation risks, including nuclear installations, the use of radiation and radioactive sources, the transport of radioactive material and the management of radioactive waste.

Safety measures and security measures<sup>1</sup> have in common the aim of protecting human life and health and the environment. Safety measures and security measures must be designed and implemented in an integrated manner so that security measures do not compromise safety and safety measures do not compromise security.

The IAEA safety standards reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation. They are issued in the IAEA Safety Standards Series, which has three categories (see Fig. 1).

### **Safety Fundamentals**

Safety Fundamentals present the fundamental safety objective and principles of protection and safety, and provide the basis for the safety requirements.

### **Safety Requirements**

An integrated and consistent set of Safety Requirements establishes the requirements that must be met to ensure the protection of people and the environment, both now and in the future. The requirements are governed by the objective and principles of the Safety Fundamentals. If the requirements are not met, measures must be taken to reach or restore the required level of safety. The format and style of the requirements facilitate their use for the establishment, in a harmonized manner, of a national regulatory framework. Requirements, including numbered ‘overarching’ requirements, are expressed

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<sup>1</sup> See also publications issued in the IAEA Nuclear Security Series.

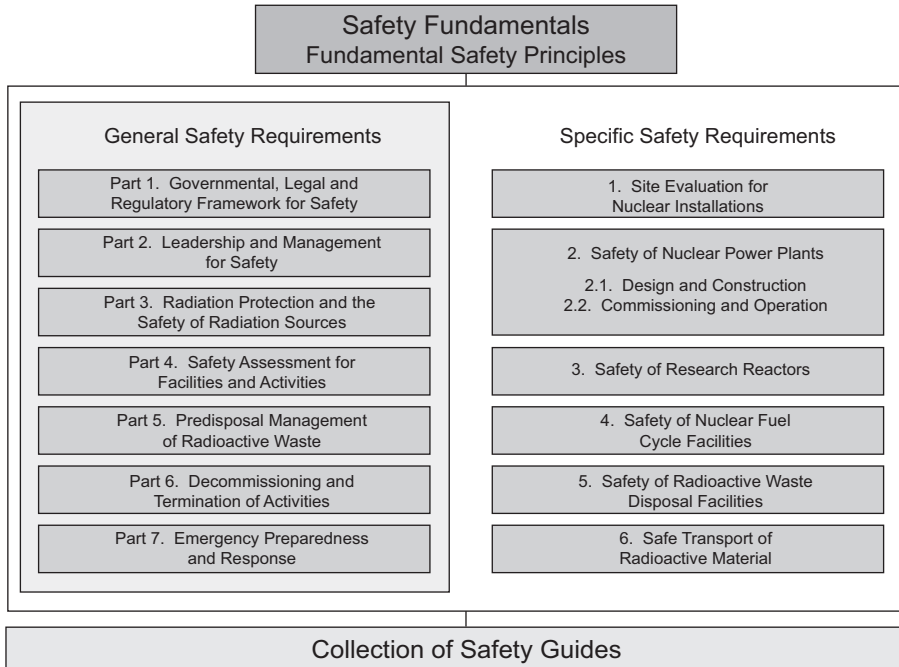


*FIG. 1. The long term structure of the IAEA Safety Standards Series.*

as ‘shall’ statements. Many requirements are not addressed to a specific party, the implication being that the appropriate parties are responsible for fulfilling them.

### Safety Guides

Safety Guides provide recommendations and guidance on how to comply with the safety requirements, indicating an international consensus that it is necessary to take the measures recommended (or equivalent alternative measures). The Safety Guides present international good practices, and increasingly they reflect best practices, to help users striving to achieve high levels of safety. The recommendations provided in Safety Guides are expressed as ‘should’ statements.

## APPLICATION OF THE IAEA SAFETY STANDARDS

The principal users of safety standards in IAEA Member States are regulatory bodies and other relevant national authorities. The IAEA safety

standards are also used by co-sponsoring organizations and by many organizations that design, construct and operate nuclear facilities, as well as organizations involved in the use of radiation and radioactive sources.

The IAEA safety standards are applicable, as relevant, throughout the entire lifetime of all facilities and activities — existing and new — utilized for peaceful purposes and to protective actions to reduce existing radiation risks. They can be used by States as a reference for their national regulations in respect of facilities and activities.

The IAEA's Statute makes the safety standards binding on the IAEA in relation to its own operations and also on States in relation to IAEA assisted operations.

The IAEA safety standards also form the basis for the IAEA's safety review services, and they are used by the IAEA in support of competence building, including the development of educational curricula and training courses.

International conventions contain requirements similar to those in the IAEA safety standards and make them binding on contracting parties. The IAEA safety standards, supplemented by international conventions, industry standards and detailed national requirements, establish a consistent basis for protecting people and the environment. There will also be some special aspects of safety that need to be assessed at the national level. For example, many of the IAEA safety standards, in particular those addressing aspects of safety in planning or design, are intended to apply primarily to new facilities and activities. The requirements established in the IAEA safety standards might not be fully met at some existing facilities that were built to earlier standards. The way in which IAEA safety standards are to be applied to such facilities is a decision for individual States.

The scientific considerations underlying the IAEA safety standards provide an objective basis for decisions concerning safety; however, decision makers must also make informed judgements and must determine how best to balance the benefits of an action or an activity against the associated radiation risks and any other detrimental impacts to which it gives rise.

## DEVELOPMENT PROCESS FOR THE IAEA SAFETY STANDARDS

The preparation and review of the safety standards involves the IAEA Secretariat and four safety standards committees, for nuclear safety (NUSSC), radiation safety (RASSC), the safety of radioactive waste (WASSC) and the safe transport of radioactive material (TRANSSC), and a Commission on Safety Standards (CSS) which oversees the IAEA safety standards programme (see Fig. 2).

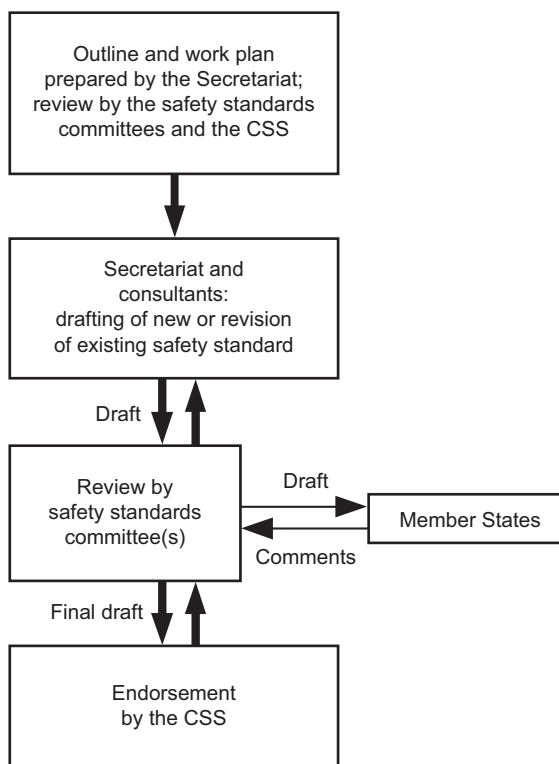


FIG. 2. The process for developing a new safety standard or revising an existing standard.

All IAEA Member States may nominate experts for the safety standards committees and may provide comments on draft standards. The membership of the Commission on Safety Standards is appointed by the Director General and includes senior governmental officials having responsibility for establishing national standards.

A management system has been established for the processes of planning, developing, reviewing, revising and establishing the IAEA safety standards. It articulates the mandate of the IAEA, the vision for the future application of the safety standards, policies and strategies, and corresponding functions and responsibilities.

## INTERACTION WITH OTHER INTERNATIONAL ORGANIZATIONS

The findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the recommendations of international

expert bodies, notably the International Commission on Radiological Protection (ICRP), are taken into account in developing the IAEA safety standards. Some safety standards are developed in cooperation with other bodies in the United Nations system or other specialized agencies, including the Food and Agriculture Organization of the United Nations, the United Nations Environment Programme, the International Labour Organization, the OECD Nuclear Energy Agency, the Pan American Health Organization and the World Health Organization.

## INTERPRETATION OF THE TEXT

Safety related terms are to be understood as defined in the IAEA Safety Glossary (see <http://www-ns.iaea.org/standards/safety-glossary.htm>). Otherwise, words are used with the spellings and meanings assigned to them in the latest edition of The Concise Oxford Dictionary. For Safety Guides, the English version of the text is the authoritative version.

The background and context of each standard in the IAEA Safety Standards Series and its objective, scope and structure are explained in Section 1, Introduction, of each publication.

Material for which there is no appropriate place in the body text (e.g. material that is subsidiary to or separate from the body text, is included in support of statements in the body text, or describes methods of calculation, procedures or limits and conditions) may be presented in appendices or annexes.

An appendix, if included, is considered to form an integral part of the safety standard. Material in an appendix has the same status as the body text, and the IAEA assumes authorship of it. Annexes and footnotes to the main text, if included, are used to provide practical examples or additional information or explanation. Annexes and footnotes are not integral parts of the main text. Annex material published by the IAEA is not necessarily issued under its authorship; material under other authorship may be presented in annexes to the safety standards. Extraneous material presented in annexes is excerpted and adapted as necessary to be generally useful.

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# 1. INTRODUCTION

## BACKGROUND

1.1. The applications of ionizing radiation bring many benefits to humankind, ranging from power generation to uses in medicine, industry and agriculture. One of the longest established industrial applications of radiation is the use of radiography for the non-destructive testing of items of equipment. Industrial radiography provides a means of verifying the physical integrity of equipment and structures such as vessels, pipes, welded joints, castings and other devices. The structural integrity of such equipment and structures affects not only the safety and quality of the products but also the protection of workers, the public and the environment.

1.2. Industrial radiography work poses a negligible risk if it is performed in a safe manner. However, experience shows that incidents involving industrial radiography sources have sometimes resulted in high doses to workers, causing severe health consequences such as radiation burns and, in a few cases, death. Members of the public have also suffered radiation overexposures when radioactive sources used for industrial radiography were not properly controlled or regulated. Contamination of people and the environment has also resulted from incidents involving corroded or damaged sources. Industrial radiography work by its nature is often carried out under difficult working conditions, such as in confined spaces or extreme cold or heat. Working under such adverse conditions might result in operational situations in which the principle of keeping doses as low as reasonably achievable is challenged. All of these aspects demonstrate the necessity for senior management to promote a safety culture within their organizations to ensure that safety comes first.

1.3. It is assumed in this Safety Guide that the State has in place an effective governmental, legal and regulatory infrastructure for radiation safety that covers industrial radiography<sup>1</sup> [1–4].

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<sup>1</sup> The term ‘industrial radiography’ is used in this Safety Guide to mean industrial radiography involving radiation sources. ‘Radiation’ as used here means ionizing radiation. The terminology used in this publication is defined and explained in the IAEA Safety Glossary, 2007 Edition [5] (see also <http://www-ns.iaea.org/standards/safety-glossary.htm>).

1.4. This Safety Guide supersedes Safety Reports Series No. 13 on Radiation Protection and Safety in Industrial Radiography<sup>2</sup>.

1.5. Unless otherwise stated, terms are used with the meanings ascribed to them in the IAEA Safety Glossary (2007 Edition) [5].

## OBJECTIVE

1.6. The International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (the BSS) [2] specify the basic requirements for protection of people against exposure to radiation and for the safety of radiation sources. The implementation of these requirements helps to ensure that the number of people exposed to radiation and their doses are kept as low as reasonably achievable, and helps to prevent incidents or to mitigate their consequences. This Safety Guide recommends how industrial radiography work should be carried out within the framework of the BSS and other IAEA safety standards.

1.7. The guidance in this publication is based on the BSS and other IAEA safety standards which are referenced in the text. The guidance in this publication is aimed primarily at managers of operating organizations that are authorized to carry out industrial radiography work, radiographers, radiation protection officers and regulators. The guidance may also be of interest to designers and manufacturers of industrial radiography equipment and facilities.

## SCOPE

1.8. This Safety Guide provides recommendations for ensuring radiation safety in industrial radiography used for purposes of non-destructive testing. This includes industrial radiography work that utilizes X ray and gamma sources, both in fixed shielded facilities that have effective engineering controls and outside shielded facilities using mobile sources (i.e. site radiography).

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<sup>2</sup> INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection and Safety in Industrial Radiography, Safety Reports Series No. 13, IAEA, Vienna (1999).

1.9. Recommendations and guidance relating to techniques of industrial radiography, such as techniques for obtaining a good image, are provided in another IAEA publication [6].

1.10. The use of gamma radiography underwater and the use of neutron radiography are relatively rare. These techniques will require the development of specialized safety assessments and specific procedures. The technical guidance for these radiography techniques are not specifically addressed in this publication, although the general safety principles apply, such as provision of adequate shielding and ensuring that radiation doses are kept as low as reasonably achievable.

1.11. The use of radiation for security screening of people and of baggage, mail, cargo and vehicles and for other such detection purposes is planned to be covered in a separate IAEA Safety Guide.

## STRUCTURE

1.12. The various duties and responsibilities of organizations and individuals are described in Section 2. The preparation of a safety assessment and its relationship to the radiation protection programme are covered in Sections 3 and 4, respectively. The necessity for operating organizations to employ trained and qualified personnel is described in Section 5. Sections 6 and 7, respectively, describe how radiation monitoring of workers and the workplace should be carried out.

1.13. Subsequent sections detail the practicalities of properly controlling gamma sources (Section 8), the physical safety of gamma and X ray sources and ancillary equipment (Section 9), the safe use of X ray and gamma sources in fixed facilities and under conditions for site radiography (Sections 10 and 11, respectively), and the safe transport of radioactive sources (Section 12). Preparedness for, and response to, emergencies involving industrial radiography sources are described in Section 13.

1.14. A summary of the IAEA categorization of radioactive sources is given in the Appendix. An example of safety assessment for industrial radiography is given in Annex I. An overview of industrial radiography sources and equipment is provided in Annex II. Finally, a short overview of examples of accidents is given in Annex III.

## 2. DUTIES AND RESPONSIBILITIES

### GENERAL

2.1. The overall responsibility for radiation safety lies with the operating organization that is authorized to carry out industrial radiography work. Specific duties and the day to day responsibilities for safe operation of the equipment will, however, lie with a range of people, including senior management, the radiation protection officer, industrial radiographers and assistants, qualified experts and, for site radiography work, the client responsible for the premises where the site radiography work is being carried out and any relevant subcontractors. All responsibilities and duties should be agreed to by all relevant parties and should be identified in writing.

### THE OPERATING ORGANIZATION

#### **Management of radiation safety and safety culture**

2.2. The operating organization, through its managers, is responsible for the establishment and implementation of the technical and organizational measures necessary to ensure protection and safety and for compliance with the relevant legal and regulatory requirements. In some cases, it may be appropriate to appoint people from outside the organization to carry out tasks or actions in relation to these responsibilities, but the operating organization retains the prime responsibility for radiation safety and regulatory compliance.

2.3. A senior manager should be designated as having overall responsibility for overseeing radiation safety and verifying that industrial radiography work is carried out in accordance with regulatory requirements. Responsibilities for radiation safety are required to be established, and they should be agreed to by all relevant parties and recorded in written form. Managers should ensure that procedures are in place for the protection of workers, the public and the environment, and for ensuring that doses are kept as low as reasonably achievable (the principle of optimization). All policies and procedures should be documented, and should be made available to all staff and the regulatory body as appropriate.

2.4. Managers are required to foster a safety culture within their organization, to encourage a questioning and learning attitude to protection and safety and to discourage complacency [2]. A good safety culture is promoted by management arrangements and workers' attitudes, which interact to foster a safe approach to the performance of work. Safety culture is not confined to radiation protection; it should also extend to conventional safety.

2.5. Operating organizations with a good safety culture do not assign blame when incidents occur; they learn from their mistakes, foster a questioning attitude and seek continuous improvement in the safety of work processes. In investigating incidents, consideration may be given to what is acceptable behaviour; however, in some cases, disciplinary measures may be taken.

### **Radiation protection programme**

2.6. The operating organization should develop, document and implement a radiation protection programme [7]. This should include information on the radiation protection arrangements, the safety assessment, the measures for implementing the arrangements, and the mechanism for the review and updating of the arrangements. Further details on the safety assessment and the radiation protection programme are given in Sections 3 and 4, respectively.

### **Management system**

2.7. The operating organization should develop, implement, assess and continually improve a management system that defines the responsibilities of all relevant persons and details the requirements for the organization, personnel and equipment. The management system should be based on national or international standards [8–10]. It should incorporate mechanisms for routine internal inspections and audits, as well as third party audits, as appropriate. The radiation protection programme should be integrated into the management system.

### **Facilities and resources**

2.8. The operating organization should ensure that suitable facilities and equipment are available, to enable radiography work to be carried out safely and in accordance with regulatory requirements. In particular, radiography equipment should incorporate all the relevant safety features and warning features. An adequate number of radiographers, assistants and radiation protection officers should be available to perform each job safely. They should be provided with

appropriate equipment (such as radiation monitors) to enable the work to be carried out safely and effectively.

### **Notification to the regulatory body**

2.9. The operating organization intending to carry out industrial radiography work should submit a notification to the regulatory body of its intention to carry out work of this type. This notification should be made prior to the commencement by the operating organization of work with radiation, and the details of the notification should be in accordance with regulatory requirements. Some regulatory bodies may require additional information to be provided on a regular basis or on a case by case basis (e.g. for site radiography work).

### **Authorization from the regulatory body**

2.10. The operating organization is required to apply to the regulatory body for an authorization to acquire, store, use, distribute or transfer radiography sources. Some States may also require an authorization for the import or export of radiography sources. Radiography work should not commence until the appropriate authorization, which may impose certain restrictions or limitations, has been received by the operating organization.

2.11. When applying for an authorization, the operating organization should provide the regulatory body with the appropriate documentary evidence to demonstrate that an adequate level of radiation safety will be afforded and maintained. Regulatory bodies, if not accepting an implicit justification, should require a formal justification from the operating organization for the use of ionizing radiation rather than alternative technologies for purposes of non-destructive testing.

2.12. The documentary evidence necessary to support an authorization request should include, as a minimum:

- (a) Information about the applicant for authorization;
- (b) The operating organization's requirements for the training and qualification of all relevant staff;
- (c) Technical information about the type(s) of radiation source(s) and equipment to be used;
- (d) A safety assessment covering the use and storage of sources;
- (e) Details of the safety system and facilities in which the radiation sources will be stored or used (e.g. shielding, interlock systems and warning systems);

- (f) A radiation protection programme;
- (g) Emergency plans and procedures.

## RADIATION PROTECTION OFFICERS

2.13. The operating organization should appoint in-house at least one employee as a radiation protection officer to oversee the day to day implementation of the radiation protection programme and to carry out the duties required by the programme. The duties of the radiation protection officer, depending on the regulatory requirements, may include:

- (a) Oversight of industrial radiography operations, to assist the operating organization to comply with regulatory requirements, including requirements for the safe transport of sources for site radiography work;
- (b) Maintenance of source accountancy records;
- (c) Inspection and maintenance of engineering controls, safety features and warning features;
- (d) Oversight of access control for controlled areas;
- (e) Establishment and periodic review of arrangements for personal dosimetry, including maintenance and review of occupational dose records;
- (f) Ensuring that radiographers are suitably trained in the use of equipment and in radiation protection, and that they receive regular refresher training;
- (g) Ensuring that emergency plans are established and that they are practised regularly;
- (h) Supervision of workplace monitoring arrangements;
- (i) Establishment, issue and periodic review of local rules (including work permits where appropriate);
- (j) Investigation of higher than usual exposures and overexposures;
- (k) Investigation and reporting of incidents, including accidents.

2.14. The number of radiation protection officers to be appointed will depend on the size of the operating organization, the number of radiography sources, and the frequency and nature of the radiography work to be carried out. In cases where more than one radiation protection officer has been appointed, the duties and responsibilities of each should be well defined. Even in small organizations consisting of only a few employees, someone with adequate knowledge, training and experience should be appointed as the radiation protection officer.

2.15. The radiation protection officer should be an employee of the company, should be appropriately qualified, should have experience of radiography and

should have a role that permits close oversight of radiography work. The operating organization should ensure that the radiation protection officer is afforded sufficient time, authority and resources to carry out their duties effectively. The radiation protection officer should also be given the authority to stop unsafe work and to interact effectively throughout the organization, especially with senior managers, to ensure that decisions that may affect radiation safety have high level support.

## QUALIFIED EXPERTS

2.16. The operating organization may consult with one or more qualified experts on matters relevant to radiation safety, such as the design of radiography facilities, radiation shielding calculations, and testing and maintenance of radiation survey meters. The responsibility for compliance with regulatory requirements cannot be delegated to the qualified expert and always remains with the operating organization.

2.17. Qualified experts do not have to be employees of the operating organization: they may be appointed on a part-time basis or for specific projects. The primary necessity is that the qualified expert should satisfy any appropriate national qualification or certification criteria.

2.18. The qualified expert should work in close cooperation with the radiation protection officer to ensure that all the necessary duties and tasks are performed.

## WORKERS

### **Radiographers**

2.19. While the primary responsibility for radiation safety lies with the operating organization, radiographers (including assistants and trainees) have a responsibility to work safely and to take all reasonable actions to restrict their own exposure and those of other workers and members of the public.

Radiographers should:

- (a) Follow the local rules (see Section 4) and any relevant procedures;
- (b) Wear their individual dosimeters in the correct place at all times during radiography work and source manipulation (see Section 6);

- (c) Use radiation monitors properly and in a systematic manner (see Section 7);
- (d) Cooperate with the radiation protection officer and qualified experts on all radiation safety issues;
- (e) Participate in any training concerning radiation safety;
- (f) Abstain from any wilful action that could put themselves or others in contravention of regulatory requirements or of the operating organization's own requirements.

2.20. The radiographer should promptly inform the radiation protection officer of any incident or circumstances that could result in higher than usual radiation doses to themselves or to other persons. This could include failures or observed deficiencies in safety systems and warning systems, errors in following procedures, or inappropriate behaviour. A written report should be made to the radiation protection officer as soon as practicable after the incident or observation.

2.21. Radiation safety should be incorporated into the daily routine of radiography work by all personnel. This is a factor by which the overall safety culture of the operating organization should be judged.

### **Radiographers on short term contracts (itinerant workers)**

2.22. Operating organizations that hire self-employed radiographers on a short term basis should ensure that the radiographers have the same level of protection and safety as radiographers employed on a full-time basis. These short term radiographers (sometimes called itinerant workers) work for only a short period of time (e.g. several weeks) with the operating organization before leaving to work for another employer.

2.23. Such working practices can create particular difficulties in relation to regulatory compliance. The relevant responsibilities of the operating organization and the itinerant radiographer should be clearly specified in the contractual arrangements. To enable them to comply with regulatory requirements, operating organizations should be aware of itinerant workers' current annual cumulative effective dose prior to their commencing work.

2.24. The responsibilities of the operating organization and the itinerant radiographer will depend on the specific regulatory requirements. The operating organization should clarify with the radiographer the allocation of responsibilities for subjects such as:

- The provision of individual dosimetry and dose record keeping (see Section 6);
- Health assessment arrangements (see Section 6);
- Workplace monitoring arrangements (see Section 7);
- Local rules (see Section 4).

2.25. The operating organization should verify that the radiographer has the appropriate qualifications and has received the necessary training in both radiation safety and industrial radiography techniques. It should verify that all procedures and other relevant documents are provided in a language known to the radiographer.

## THE CLIENT

2.26. The client is the organization or person responsible for hiring the operating organization to perform industrial radiography work. The client should always use an operating organization that is authorized by the regulatory body in accordance with regulatory requirements for industrial radiography.

2.27. The client should give the operating organization sufficient lead time to plan the work and to carry it out safely, and to enable compliance with any advance notifications required by the regulatory body.

2.28. The client should not impose contractual conditions or limitations that would hinder the operating organization from performing radiography work in a safe manner. Regulatory requirements and safety requirements take precedence over commercial requirements. The client should ensure that radiography work is coordinated with other work on-site, to minimize the risks to radiographers arising from site specific hazards and to minimize radiation exposures to other workers. There should be special coordination if more than one radiography organization is working on the client's site at one time. A permit-to-work system can facilitate communication and coordination of different jobs on the same site.

2.29. The client is responsible for ensuring a safe working environment for the radiographers, including the provision of scaffolding, adequate lighting and safe arrangements for working in vessels, confined spaces, trenches or other places where access might be necessary. The client is also responsible for informing visiting radiographers about safety issues that are site specific and/or providing them with any necessary training thereon.

2.30. If radioactive sources are to be stored temporarily on the client's site, both the client and the operating organization should ensure that such stores are safe and secure, and that any necessary authorizations are obtained from the regulatory body. Procedures for gaining access to the source store should be clearly defined in relation to the client and the operating organization. (See also Section 7.)

### **3. SAFETY ASSESSMENT**

#### **GENERAL**

3.1. The operating organization should conduct and document a safety assessment for each type of radiation source for which they are authorized. For sources and devices of an identical type, it may be acceptable to make one generic safety assessment. The initial safety assessment, sometimes called a 'prior radiological evaluation', is the primary tool for determining which protection measures should be taken, and for confirming that all parameters that have a bearing on protection and safety are considered. The safety assessment should be documented and independently reviewed within the operating organization's management system.

3.2. A safety assessment should be carried out before the source is first received at the site or before it is used for the first time. The operating organization should plan ahead, to ensure that there is sufficient time for the required protection and safety measures to be put into place. A new safety assessment may not be necessary for the replacement of one source with an identical one.

3.3. In the event of work already being carried out where no safety assessment has previously been made, the operating organization should carry out a retrospective safety assessment. The retrospective safety assessment should either confirm that all the relevant protective measures are in place or identify any additional measures that should be put in place.

## METHODOLOGY FOR THE SAFETY ASSESSMENT

3.4. Industrial radiography sources produce high dose rates and hence should be subject to a comprehensive safety assessment. The radiation risks arising from routine use of the radiation source(s) together with the probability and magnitude of potential exposures arising from incidents should be taken into account in the safety assessment. An example of a safety assessment for industrial radiography is given in Annex I. The safety assessment should include:

- (a) Consideration of the dose rates from both shielded and unshielded radioactive sources and X ray generators;
- (b) Potential exposures of radiographers, other workers and the public, for a range of scenarios representing normal use and reasonably foreseeable incidents;
- (c) Limits and technical conditions for operation of sources;
- (d) Ways in which structures, systems and components, as well as procedures relating to protection and safety, might fail or might otherwise lead to potential exposures, and the consequences of such failures;
- (e) Ways in which external factors could affect protection and safety;
- (f) Ways in which operating errors and human factors could affect protection and safety;
- (g) Evaluation of the implications of any proposed modifications for protection and safety.

## OUTCOMES OF THE SAFETY ASSESSMENT

3.5. The safety assessment should provide a basis for decision making in relation to:

- (a) The engineered control measures that are required for safety;
- (b) The development of procedures to be followed by the radiographers (the local rules);
- (c) Requirements and procedures for designating controlled areas and supervised areas;
- (d) Any requirements for protection of the public;
- (e) Information on reasonably foreseeable incidents, including the measures required to minimize the likelihood of these incidents occurring and the necessary emergency equipment;

- (f) Information on actions to be taken to restrict exposures of people and for protection of the environment in an incident (including emergency preparedness plans).

## REVIEWS OF THE SAFETY ASSESSMENT

3.6. The safety assessment should be reviewed whenever any of the following factors apply:

- (a) Safety may be compromised or affected as a result of modifications to facilities or to procedures, or the acquisition of a new radiation source or a source with different radiation characteristics.
- (b) Operating experience or investigation of emergencies or incidents, failures or errors indicates that current safety measures are invalid or are not fully effective.
- (c) Any significant changes to relevant guidelines, standards or regulations have been made or are envisaged.

## 4. RADIATION PROTECTION PROGRAMME

### OBJECTIVES AND SCOPE

4.1. The radiation protection programme is a key factor in relation to the development and maintenance of safety culture within an organization [7], and it should meet the regulatory requirements. The radiation protection programme should cover the operating organization's management structure, policies, responsibilities, procedures and organizational arrangements. All of these are in place to control radiation hazards, to optimize radiation protection measures, to prevent or reduce exposures, and to mitigate the consequences of incidents.

4.2. The radiation protection programme should be customized and scaled to meet the needs of the operating organization. The programme should reflect the complexities and hazards associated with the activities planned to be conducted for radiography purposes. The programme should be based on the operating organization's safety assessment, and it should address both planned exposure situations and potential exposures.

4.3. The elements of a radiation protection programme described here are representative of routine radiography operations with X ray and gamma sources. Operating organizations should take into account any additional measures and programmes necessary to address unique or unusual workplace hazards.

## STRUCTURE AND CONTENT

4.4. The radiation protection programme should cover the main elements contributing to protection and safety. The structure and contents of the radiation protection programme should be documented to an appropriate level of detail. The radiation protection programme should include as essential elements:

- (a) Management structure and policies;
- (b) Assignment of individual responsibilities for radiation safety;
- (c) Education and training programme on the nature of the radiation hazards, and protection and safety;
- (d) Local rules and supervision;
- (e) Designation of controlled or supervised areas;
- (f) Arrangements for monitoring workers and the workplace, including the acquisition and maintenance of instruments for radiation protection purposes;
- (g) A health surveillance programme;
- (h) A system for recording and reporting all relevant information relating to the control of exposures, decisions regarding measures for occupational radiation protection and safety, and monitoring of individuals;
- (i) Emergency preparedness plans;
- (j) Methods for periodically reviewing and auditing the performance of the radiation protection programme;
- (k) Quality assurance and process improvement.

4.5. These elements of a radiation protection programme, which are more fully described in the following, may be incorporated into a single document or a series of documents, depending on the scale and complexity of operations.

## MANAGEMENT STRUCTURE AND POLICIES

4.6. The radiation protection programme should include a description of the management structure as it relates to radiation safety. This structure, which may be presented in the form of an organizational chart, should show the names of the

senior managers responsible for radiation safety and of the various duty holders (e.g. the radiation protection officer). The chart should clearly show the line of reporting, from the radiographer through to the senior manager with overall responsibility. If the operating organization has more than one location of operations, the management structure should clearly specify the responsible persons at each location.

4.7. The radiation protection programme should include the company policies on radiation safety, and should include a commitment by the management to keeping radiation doses as low as reasonably achievable and to fostering a safety culture.

### **Assignment of responsibilities for radiation safety**

4.8. Responsibilities for radiation safety should be assigned to cover the entire lifetime of sources, from ordering and receipt, use and storage, to their eventual return to the supplier (or other possible end-of-life considerations). The posts for which responsibilities are allocated should include the senior managers of the operating organization (which has the prime responsibility for safety), the radiation protection officer, the qualified expert, radiographers and other workers, as described in Section 2.

4.9. For operating organizations performing radiography work on a client's premises, complying with some safety requirements (e.g. for the provision of information in relation to site specific hazards and safety requirements) should, where appropriate, be the responsibility of the client company rather than of the operating organization. At least one person from the industrial radiography organization should be given the responsibility to liaise with the client. This liaison process should include the identification of any hazards on the site, discussion of local rules, and exchange of safety related information.

### **Programme of education and training**

4.10. The radiation protection programme should describe the full scope of the training programme in protection and safety for all employees directly involved in routine radiography activities and emergency operations (see Section 5). It should include a radiation 'awareness' programme, where appropriate, for other staff. Other staff includes managers, radiographers, trainees, workers such as cleaners and maintenance staff who may be inadvertently exposed, and contractors. The radiation protection programme should also specify the minimum educational and professional qualifications for all relevant staff,

especially the radiation protection officer, radiographers and their assistants, in accordance with regulatory requirements.

4.11. The requirements for keeping training records should be consistent with regulatory requirements and recommendations, and they should be specified in the radiation protection programme.

### **Local rules and supervision**

4.12. Local rules that describe the procedures for carrying out radiography work should be developed and written in a language known by the people who will follow them. These local rules should cover all procedures associated with radiography work where there is the potential for radiation exposure, such as routine operations, source exchanges and transport (see Sections 10 and 11). The local rules are an important tool in the restriction of radiation doses. They should include sufficient information and guidance to allow radiographers and other workers to carry out their duties safely and in compliance with regulatory requirements.

4.13. Management should ensure that all relevant persons have read and understood the local rules. A copy should be provided to all radiographers and other relevant persons, and additional copies should be available in the work area. In smaller organizations with a limited amount of radiography work, it may be appropriate to have one set of local rules covering all procedures.

4.14. In larger organizations, it might be appropriate to have several sets of specific local rules. Such sets might comprise procedures for carrying out radiography work in shielded radiography enclosures<sup>3</sup>, procedures for carrying out site radiography work and procedures for exchanging gamma sources. Some client organizations might also require specific local rules to be drawn up to cover radiography work on their premises.

4.15. The operating organization should appoint at least one employee as a radiation protection officer to oversee the day to day implementation of the radiation protection programme and to carry out duties as required by the programme. Details of the duties of the radiation protection officer are given in Section 2.

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<sup>3</sup> ‘Shielded radiography enclosures’ are hereinafter referred to as ‘shielded enclosures’.

## **Designation of controlled areas or supervised areas**

4.16. The radiation protection programme should describe how controlled areas<sup>4</sup> and supervised areas<sup>5</sup> are to be designated for the conduct of industrial radiography work. Controlled areas should be used to restrict exposures in industrial radiography work. Supervised areas should sometimes be used, particularly around fixed radiography facilities. The designation of such areas should be based on the safety assessment and the measured dose rates. Guidance should be provided on setting up controlled areas, especially for site radiography work (see Sections 10 and 11).

## **Programme of workplace monitoring**

4.17. The radiation protection programme should describe the programme for the selection, calibration, maintenance and testing of equipment to measure radiation dose rates. A programme for the routine use of the monitoring equipment should be specified. The programme should provide information on the necessary frequency of dose rate measurements around fixed facilities, the monitoring procedures to be followed in carrying out site radiography work, the details to be recorded and the length of time for which the records should be kept.

4.18. The radiation protection programme should specify that an adequate number of suitable radiation monitors will be made available to the radiographers. For site radiography work, the minimum number of radiation monitors is one operational dose rate meter for each source in use, although one dose rate meter per radiographer is preferable (see Section 7).

4.19. The radiation protection programme should include dose rate reference levels. These reference levels are the maximum dose rates that are acceptable during the performance of specific tasks, such as at controlled area barriers during site radiography work and at the operator's position. Such dose rate reference levels should be consistent with regulatory requirements and guidance.

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<sup>4</sup> A controlled area is a defined area in which specific protection measures and safety provisions are or could be required for: (a) controlling normal exposures or preventing the spread of contamination during normal working conditions; and (b) preventing or limiting the extent of potential exposures.

<sup>5</sup> A supervised area is a defined area not designated a controlled area but for which occupational exposure conditions are kept under review, even though no specific protective measures or safety provisions are normally needed.

## **Arrangements for individual dose monitoring**

4.20. The radiation protection programme should specify the types of dosimeters to be used by workers, the period of wearing, and arrangements for the assessment of dosimeters and dose record keeping. The radiation protection programme should also specify that the dosimetry service provider should be appropriately approved or accredited. The radiation protection officer should review the dose records periodically to identify doses that may be higher than usual (see Section 6), and to review whether doses are as low as reasonably achievable.

## **Health surveillance programme**

4.21. The radiation protection programme should include details of a programme for periodic health surveillance of radiographers and other employees as appropriate. This should include a requirement to assess the initial and continuing fitness of workers for their intended tasks. A qualified expert and/or an appropriately qualified medical doctor should be consulted in the drawing up of the programme for health surveillance, and it should be consistent with regulatory requirements.

## **Emergency preparedness plans**

4.22. The radiation protection programme should include emergency preparedness and response plans that are to be implemented in the event of an emergency. Plans should be provided to cover all reasonably foreseeable emergencies. Guidance on emergency preparedness is provided in Section 13.

## **Periodic reviews and audits of the performance of the radiation protection programme**

4.23. As an integral part of the operating organization's management system, the radiation protection programme and its implementation should be assessed on a regular basis. This periodic review should identify problems to be addressed and any modifications that could improve the effectiveness of the radiation protection programme.

4.24. A key part of this periodic review process is a routine series of workplace audits, including the designation and qualifications of the persons who will conduct them, their frequency, the expectations of the audit team, and the reporting of results and their follow-up.

## **Quality assurance and process improvement**

4.25. Industrial radiography work and its associated activities should be carried out in accordance with the established management system. This management system should be designed to ensure that all equipment and safety systems are regularly checked and tested, and that any faults or deficiencies are brought to the attention of the management and are promptly remedied.

4.26. The management should also ensure that the correct operational procedures are being followed, and that the quality assurance programme specifies the relevant checks and audits to be made and the records to be kept. The relevant regulatory requirements should be taken into account and reflected in the content and details of the quality assurance programme.

4.27. The management system should include a mechanism for the collection and feedback of lessons learned from emergencies and incidents (including those reported both within the organization and in external reports), and how these lessons can be used to enhance safety.

## **RECORD OF THE SAFETY ASSESSMENT**

4.28. The main basis for the radiation protection programme is the safety assessment, which identifies the nature and extent of the radiation hazards that may be encountered in the course of industrial radiography operations. The report of the safety assessment should form an integral part of the documentation of the radiation protection programme.

## **RADIATION SAFETY COMMITTEE**

4.29. In medium to large sized radiography companies, a radiation safety committee should be established for the purpose of regularly reviewing the performance of the radiation protection programme. This committee may be dedicated to radiation safety or it may have other (conventional) safety related responsibilities. The committee should include the senior manager(s) responsible for radiation safety, the radiation protection officer(s), radiographer(s) and representatives of the workforce. The responsibilities of the radiation safety committee should include, but not be limited to:

- (a) Regular reviews of all aspects of the radiation protection programme;
- (b) Reviews of occupational radiation doses and any accident reports prepared by the radiation protection officer;
- (c) Making recommendations for improvements in the radiation protection programme;
- (d) Provision of guidance and direction on the performance of the radiation protection officer's duties;
- (e) Preparation and dissemination of regular reports to all staff about relevant radiation safety issues.

## 5. TRAINING AND QUALIFICATION

### GENERAL

5.1. Persons performing industrial radiography work are responsible for ensuring that their work is carried out safely and in compliance with all relevant regulations and safety standards. Operating organizations should, therefore, ensure that radiography work is carried out only by radiographers and assistants who are qualified or certified, and who are competent and trained in protection and safety.

5.2. There are internationally recognized schemes for the training and qualification of radiographers utilizing techniques of non-destructive testing. Some of these schemes may include only a limited amount of training in radiation safety. In this case, they should be supplemented with additional training specifically in protection and safety. Such additional training may be provided by specialized training organizations rather than by the operating organization.

### DESIGN OF A TRAINING PROGRAMME

5.3. Training courses in protection and safety may be provided by a range of training providers, including colleges, universities, radiation protection institutions and training consultants [11, 12]. Some States also have access to a centralized training facility, which may be a national or regional training centre that is supported by the IAEA. These training centres may offer training courses in radiation safety that are specially developed for industrial radiographers.

5.4. Radiography personnel should be classified into different levels of competence on the basis of their training and experience. In some States, for example, these levels are designated as assistant radiographer (i.e. trainee) and radiographer (i.e. a person who is fully qualified), or as Level 1 radiographer and Level 2 radiographer. Some States also have Level 3 radiographers, who can carry out training, set examinations and carry out assessments of other radiographers.

5.5. Programmes should be established for the different levels of training corresponding to the responsibilities of the radiographer. The training programme should establish the criteria for passing written and practical examinations, as well as the procedures to be followed if an applicant fails an examination. The details of the training programme should be incorporated into the radiation protection programme. Further details about training are given in the following.

## STRUCTURE AND CONTENT OF THE TRAINING COURSE

5.6. Each training course should be structured around specific aims and objectives and should be customized to the needs of the target audience. Information on the structure and content of training courses in radiation protection for industrial radiographers can be found in Refs [11, 12]. A summary of the essential elements for basic training in radiation safety for industrial radiographers is given in the following.

### **Fundamental concepts and measurements**

- Basic radiation concepts;
- Radiation quantities and units;
- Radiation detecting instruments;
- Biological effects of radiation.

### **Principles of radiation protection**

- System of radiation protection (justification, optimization and dose limitation);
- Regulatory requirements;
- Designation of controlled areas and of supervised areas;
- Dose limits and investigation levels.