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IAEA SAFETY STANDARDS SERIES

Radiation Protection and Radioactive Waste Management in the Operation of Nuclear Power Plants

SAFETY GUIDE

No. NS-G-2.7

INTERNATIONAL
ATOMIC ENERGY AGENCY
VIENNA

This publication has been superseded by SSG-40 and GSG-7.

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IAEA SAFETY STANDARDS

Under the terms of Article III of its Statute, the IAEA is authorized to establish standards of safety for protection against ionizing radiation and to provide for the application of these standards to peaceful nuclear activities.

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Safety Fundamentals (blue lettering) present basic objectives, concepts and principles of safety and protection in the development and application of nuclear energy for peaceful purposes.

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Information on the IAEA's safety standards programme (including editions in languages other than English) is available at the IAEA Internet site

www.iaea.org/ns/coordinet

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RADIATION PROTECTION AND RADIOACTIVE WASTE MANAGEMENT IN THE OPERATION OF NUCLEAR POWER PLANTS

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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''.

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FOREWORD

by Mohamed ElBaradei
Director General

One of the statutory functions of the IAEA is to establish or adopt standards of safety for the protection of health, life and property in the development and application of nuclear energy for peaceful purposes, and to provide for the application of these standards to its own operations as well as to assisted operations and, at the request of the parties, to operations under any bilateral or multilateral arrangement, or, at the request of a State, to any of that State's activities in the field of nuclear energy.

The following bodies oversee the development of safety standards: the Commission on Safety Standards (CSS); the Nuclear Safety Standards Committee (NUSSC); the Radiation Safety Standards Committee (RASSC); the Transport Safety Standards Committee (TRANSSC); and the Waste Safety Standards Committee (WASSC). Member States are widely represented on these committees.

In order to ensure the broadest international consensus, safety standards are also submitted to all Member States for comment before approval by the IAEA Board of Governors (for Safety Fundamentals and Safety Requirements) or, on behalf of the Director General, by the Publications Committee (for Safety Guides).

The IAEA's safety standards are not legally binding on Member States but may be adopted by them, at their own discretion, for use in national regulations in respect of their own activities. The standards are binding on the IAEA in relation to its own operations and on States in relation to operations assisted by the IAEA. Any State wishing to enter into an agreement with the IAEA for its assistance in connection with the siting, design, construction, commissioning, operation or decommissioning of a nuclear facility or any other activities will be required to follow those parts of the safety standards that pertain to the activities to be covered by the agreement. However, it should be recalled that the final decisions and legal responsibilities in any licensing procedures rest with the States.

Although the safety standards establish an essential basis for safety, the incorporation of more detailed requirements, in accordance with national practice, may also be necessary. Moreover, there will generally be special aspects that need to be assessed on a case by case basis.

The physical protection of fissile and radioactive materials and of nuclear power plants as a whole is mentioned where appropriate but is not treated in detail; obligations of States in this respect should be addressed on the basis of the relevant instruments and publications developed under the auspices of the IAEA. Non-radiological aspects of industrial safety and environmental protection are also not explicitly considered; it is recognized that States should fulfil their international undertakings and obligations in relation to these.

The requirements and recommendations set forth in the IAEA safety standards might not be fully satisfied by some facilities built to earlier standards. Decisions on the way in which the safety standards are applied to such facilities will be taken by individual States.

The attention of States is drawn to the fact that the safety standards of the IAEA, while not legally binding, are developed with the aim of ensuring that the peaceful uses of nuclear energy and of radioactive materials are undertaken in a manner that enables States to meet their obligations under generally accepted principles of international law and rules such as those relating to environmental protection. According to one such general principle, the territory of a State must not be used in such a way as to cause damage in another State. States thus have an obligation of diligence and standard of care.

Civil nuclear activities conducted within the jurisdiction of States are, as any other activities, subject to obligations to which States may subscribe under international conventions, in addition to generally accepted principles of international law. States are expected to adopt within their national legal systems such legislation (including regulations) and other standards and measures as may be necessary to fulfil all of their international obligations effectively.

EDITORIAL NOTE

An appendix, when included, is considered to form an integral part of the standard and to have the same status as the main text. Annexes, footnotes and bibliographies, if included, are used to provide additional information or practical examples that might be helpful to the user.

The safety standards use the form 'shall' in making statements about requirements, responsibilities and obligations. Use of the form 'should' denotes recommendations of a desired option.

The English version of the text is the authoritative version.

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. In the IAEA safety standards programme, revision of the Safety Requirements and Safety Guides in the area of the operation of nuclear power plants has been a priority. The Code on the Safety of Nuclear Power Plants: Operation, published in 1988, has been superseded by Safety of Nuclear Power Plants: Operation, Safety Standards Series No. NS-R-2 [1].

1.2. Attention has been focused on revising the various Safety Guides that provide recommendations on how to ensure the fulfilment of the revised requirements. The Safety Guide, Safety Series No. 50-SG-O5, Radiation Protection During the Operation of Nuclear Power Plants, published in 1983, was not consistent with Safety Series No. 115, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (the BSS), published in 1996 [2].

1.3. The present Safety Guide supersedes Safety Series No. 50-SG-O5, Radiation Protection during the Operation of Nuclear Power Plants, and Safety Series No. 50-SG-O11, Operational Management for Radioactive Effluents and Waste Arising in Nuclear Power Plants, published in 1986.

1.4. This Safety Guide provides recommendations on fulfilling the requirements established in Refs [1, 2] together with the principles and the requirements established in: Safety Series No. 120, Radiation Protection and the Safety of Radiation Sources [3]; Safety Series No. 111-F, The Principles of Radioactive Waste Management [4]; and Safety Standards Series No. WS-R-2, Predisposal Management of Radioactive Waste, Including Decommissioning [5].

1.5. Recommendations and guidance on radiation safety and waste management that were provided in other IAEA publications have been consulted in the preparation of this Safety Guide and are referenced in the text. The references include Safety Guides on Occupational Radiation Protection [6] and on Regulatory Control of Radioactive Discharges to the Environment [7].

OBJECTIVE

1.6. The purpose of this Safety Guide is to provide recommendations to the regulatory body, focused on the operational aspects of radiation protection and radioactive waste management in nuclear power plants, and on how to ensure the fulfilment of the requirements established in the relevant Safety Requirements publications. It will also be useful for senior managers in licensee or contractor organizations who are responsible for establishing and managing programmes for radiation protection and for the management of radioactive waste.

SCOPE

1.7. This Safety Guide gives general recommendations for the development of radiation protection programmes at nuclear power plants. The issues are then elaborated by defining the main elements of a radiation protection programme. Particular attention is paid to area classification, workplace monitoring and supervision, application of the principle of optimization of protection (also termed the ‘as low as reasonably achievable’ (ALARA) principle), and facilities and equipment.

1.8. This Safety Guide covers all the safety related aspects of a programme for the management of radioactive waste at a nuclear power plant. Emphasis is placed on the minimization of waste in terms of both activity and volume. The various steps in predisposal waste management are covered, namely processing (pretreatment, treatment and conditioning), storage and transport. Releases of effluents, the application of authorized limits and reference levels are discussed, together with the main elements of an environmental monitoring programme.

1.9. This Safety Guide does not address the decommissioning of nuclear power plants, which is the subject of Ref. [8].

STRUCTURE

1.10. Section 2 summarizes the relevant requirements for radiation protection and radioactive waste management in the operation of nuclear power plants, such as the application of dose limits and application of the principle of optimization as well as organizational aspects. Recommendations for setting up a radiation protection programme for the operation of a nuclear power plant are given in Section 3. Section 4 recommends appropriate actions for keeping the generation of radioactive waste to a minimum, for the safe handling and processing of radioactive waste, and for the monitoring and control of effluents and discharges. Section 5 outlines a programme for training as a crucial element in radiation protection and radioactive waste management. Appropriate record keeping for all areas covered by this Safety Guide is described in Section 6. Annex I gives an example of a classification of radiation zones. Annex II describes general ways of reducing releases of radioactive substances to the environment. Annex III gives the typical characteristics of waste classes.

2. APPLICABLE REQUIREMENTS AND OBJECTIVES

APPLICABLE REQUIREMENTS

2.1. The following requirements and principles established in the relevant safety standards [1–4] apply to the protection of site personnel (all persons working in the site area), members of the public and the environment against ionizing radiation during the operating lifetime of a nuclear power plant.

2.2. "No practice or source within a practice should be authorized unless the practice produces sufficient benefit to the exposed individuals or to society to offset the radiation harm that it might cause; that is: unless the practice is justified, taking into account social, economic and other relevant factors" (Ref. [2], para. 2.20). For the purposes of this Safety Guide it is presupposed that the operation of a nuclear power plant is justified. Such a decision goes beyond the scope of protection and safety alone and is made largely on the basis of broader economic, social and political concerns.

2.3. "The normal exposure of individuals shall be restricted so that neither the total effective dose nor the total equivalent dose to relevant organs or tissues, caused by the possible combination of exposures from authorized practices, exceeds any relevant dose limit specified in Schedule II, except in special circumstances provided for in Appendix I" (Ref. [2], para. 2.23). In nuclear power plants, dose limitation should be applied to:

— doses due to occupational exposures incurred in the plant by the personnel of the operating organizations;
— doses due to occupational exposures incurred in all plants and facilities by contractors;
— doses due to exposures incurred by members of the public as a result of activities in radioactive waste management and effluent discharges deriving from the nuclear power plant.

Account should be taken of doses due to exposures arising from other sources and facilities.

2.4. "In relation to exposures from any particular source within a practice, except for therapeutic medical exposures, protection and safety shall be optimized in order that the magnitude of individual doses, the number of people exposed and the likelihood of incurring exposures all be kept as low as reasonably achievable, economic and social factors being taken into account, within the restriction that the doses to individuals delivered by the source be subject to dose constraints" (Ref. [2], para. 2.24). In a nuclear power plant, protection and safety should be optimized with regard to occupational exposure to any particular source or any particular task in the plant, and in relation to public exposure to radioactive waste and effluent discharges deriving from that plant. In these optimizations, possible trade-offs between occupational exposure and public exposure should be considered.

2.5. "All reasonably practicable measures shall be taken to enhance operational safety, to prevent radiation accidents and to mitigate their consequences should they occur" (Ref. [3], Principle 4). Controls for radiation protection during operation of the plant, including the management of radioactive effluents and waste arising in the plant, should be directed not only to protecting workers and members of the public from radiation exposure, but also to preventing or reducing potential exposures and mitigating their potential consequences.

2.6. The basic obligations required for interventions in accident situations are:

(a) "In order to reduce or avert exposures in intervention situations, protective actions or remedial actions shall be undertaken whenever they are justified" (Ref. [2], para. 3.3).
(b) "The form, scale and duration of any such protective action or remedial action shall be optimized so as to produce the maximum net benefit, understood in a broad sense, under the prevailing social and economic circumstances" (Ref. [2], para. 3.4).

The intervention should accordingly be made on the basis of emergency plans prepared by the operating organization. These plans should be co-ordinated with those of all other bodies having responsibilities in an emergency, including public authorities, and should be submitted to the regulatory body [1].

2.7. "The objective of radioactive waste management is to deal with radioactive waste in a manner that protects human health and the environment now and in the future without imposing undue burdens on future generations" (Ref. [4], para. 201). Operational management should be implemented as part of a national strategy. It is required in particular to comply with Principles 7–9 of Ref. [4]:

- "Generation of radioactive waste shall be kept to the minimum practicable;
- Interdependences among all steps in radioactive waste generation and management shall be appropriately taken into account;
- The safety of facilities for radioactive waste management shall be appropriately assured during their lifetime."

These principles are reflected in the requirements established in paras 8.8 and 8.9 of Ref. [1], one of which is that "The operating organization shall establish and implement a programme to manage radioactive waste safely" (Ref. [1], para. 8.9).

2.8. A requirement for the operation of a nuclear power plant is that "The operating organization shall establish and implement a programme to ensure that, in all operational states, doses due to exposure to ionizing radiation… in the plant or due to any planned releases of radioactive material from the plant are kept below prescribed limits and as low as reasonably achievable" (Ref. [1], para. 8.1).

APPLICATION OF DOSE LIMITS

2.9. The operating organization of the nuclear power plant is required to ensure that doses conform to the dose limits specified by the regulatory body in respect of the exposure of workers and of members of the public (Ref. [2], paras I.4 and III.2). These dose limits should be in accordance with those specified in Schedule II of the BSS. Guidance on how to verify compliance with the dose limits for workers is given in the Safety Guide on Occupational Radiation Protection [6].

2.10. In normal plant operation, it may happen that site personnel receive doses in excess of a dose limit, either inadvertently or as a consequence of a violation of procedures. Any such event should be thoroughly investigated and reported to the regulatory body. If it is suspected that a substantial overexposure has occurred, senior managers should promptly undertake investigations involving specialists in different fields, including in particular a physician and a radiation protection officer. Arrangements should be made to ensure that the appropriate lessons are drawn and that actions are taken to prevent a recurrence. Further guidance on the management of overexposed workers is given in Ref. [6].

2.11. In a nuclear or radiological emergency it may be justified to exceed the prescribed dose limits, for the purposes of: saving life; preventing serious injury; undertaking actions intended to avert a large collective dose; or undertaking actions to prevent the development of catastrophic conditions. Details of procedures and possible exposure levels in emergency actions are given in Ref. [6].

2.12. Doses resulting from events as described in paras 2.10 and 2.11 should be recorded separately from, but together with doses recorded in routine monitoring. An overexposure should not necessarily preclude a worker from continuing to work in areas of radiation exposure. However, the regulatory body, with due regard for the health of the worker, should consider whether there is sufficient reason to prevent his or her continuing in radiation related work. If he or she can continue in such work, the operating organization — possibly in consultation with the medical practitioner and with the overexposed worker, directly or through his or her representatives where appropriate — should consider temporary reductions in the dose limits and the periods for which these restrictions apply. Such temporary dose restrictions should comply either with national regulations or with the requirements of the regulatory body.

2.13. Radiation exposure of members of the public may arise as a result of discharges of radioactive materials from the nuclear power plant, in gaseous or liquid form, and/or by direct irradiation from the plant itself. Discharges should be controlled in accordance with authorizations granted by the regulatory body, such that radiation doses to the most exposed members of the public (the critical group) in the vicinity of the plant are within the dose constraint (see paras 2.21, 2.25). The dose constraint assigned by the regulatory body to this source of exposure should be a fraction of the dose limit for the public. The authorized discharge level should be set by using environmental modelling techniques to establish the relationship between the release level and the potential dose to the critical group, with due account taken of all expected pathways of exposure. Verification of compliance with the discharge authorization should be obtained by monitoring at the source of the discharge complemented by monitoring in the environment (see Ref. [7] for further details).

OPTIMIZATION OF PROTECTION

Objectives and tasks

2.14. The optimization of protection and safety measures, or the application of the ALARA principle (to keep doses as low as reasonably achievable, economic and social factors being taken into account), should be carried out at all stages during the lifetime of the equipment and installations. In the optimization, all relevant factors should be taken into account, such as:

(a) the balance between doses to workers and doses to the public;
(b) the balance between present doses due to discharges and future doses due to confinement of the same radioactive substances solidified as waste;

(c) exposures arising from different tasks;
(d) requirements relating to nuclear safety, conventional safety and radiation protection;
(e) options for radioactive waste management and decommissioning.

The trade-offs between the various factors should be considered, for example, by means of decision aiding techniques such as multicriteria methods [9, 10].

2.15. The operating organization should participate in activities relating to the design of modifications to components of the existing plant so as to assist in ensuring that the requirements for radiation protection and waste management are met. Moreover, applicable operating experience should be transferred to the suppliers of redesigned reactors and to the designers of new reactor types. Such participation will help in the collection of information that should be used for the preparation of operational procedures.

2.16. The process of optimization may range from intuitive qualitative analysis, using experience from acknowledged good practices or professional judgement, to quantitative analysis using decision aiding techniques. Whichever method is used, it should be sufficiently comprehensive for all relevant factors to be taken into account in a coherent way.

2.17. When a structured quantitative approach seems to be appropriate for the selection of measures, the decision should result from the application of the optimization procedure. This procedure should include the following successive steps:

(a) All relevant radiological, economic and social factors for a particular situation under review, such as the distribution of individual doses and collective doses for site personnel and the public, the impacts on future generations and the investment costs, should be identified;
(b) All possible options for protection that may potentially reduce doses due to occupational or public exposure should be identified;
(c) Where possible, the relevant factors for each option should be quantified;
(d) All options should be compared and the optimal one selected;
(e) If appropriate, a sensitivity analysis should be performed; that is, the robustness of the solutions obtained should be evaluated by testing the results for different values of the key parameters for which there are recognized uncertainties.

Further guidance on the implementation of a programme for the optimization of protection in occupational exposure is given in Refs [6, 9] and in a Safety Report on Optimization of Radiation Protection in the Control of Occupational Exposure [10].

2.18. The process of optimization of protection in operation should begin at the planning stage and should continue through the stages of scheduling, preparation, implementation and feedback. This process of optimization through work management should be applied in order to keep exposure levels under review and to ensure that doses are as low as reasonably achievable [10, 11]. The management of the operating organization should be committed to implementing measures for radiation protection appropriately and to specifying the means available for such implementation. Guidance on the application of the principle of optimization is given in Section 3.

2.19. Operational considerations for a dose control programme include the actions to be taken once the plant is operating in order to optimize doses to workers involved in routine operation, maintenance, repairs, refuelling, plant modifications, in-service inspection and waste management (the handling, transfer, storage and disposal of radioactive waste). Such actions should include actions for reducing the amount of radioactive products in reactor systems, as described in Section 3.

Constraints

2.20. The optimization of the measures for protection and safety associated with any particular source or operation in a practice should be subject to dose constraints.

2.21. A dose constraint is a source related value of individual dose used to restrict the range of options considered in the process of optimization. A dose constraint is not a limit but a ceiling on the values of individual dose that should be considered acceptable in the optimization process. It is used prospectively for the planning and executing of tasks as well as for design purposes.

2.22. In order to apply the principle of optimization, individual doses should be assessed at the operational planning stage, and the predicted individual doses for the various options should be compared with the appropriate dose constraint. Options predicted to give estimated doses that would exceed the constraint should normally be rejected.

2.23. For occupational exposure in a nuclear power plant, the constraint should be related to a particular task or a complete operation. It should therefore be set by the operating organization on a case by case basis according to the specific circumstances of the exposure. The regulatory body, rather than itself stipulating values of constraints, should generally encourage the operating organization of the plant to develop constraints, subject to regulatory control.

2.24. The process of deriving the value of a constraint for doses due to occupational exposure for any specific circumstances should include a review of operating experience and of experience derived from similar circumstances, if possible, together with consideration of economic, social and technical factors. For occupational exposure, experience from previous well managed operations should be considered of particular importance in setting constraints. Large national or international databases with data on the doses associated with specific tasks should be used in setting constraints.

2.25. For public exposure, the dose constraint should be used to restrict the annual doses that members of the public could receive from the planned operation of the particular plant. In setting the dose constraint for a particular plant, the regulatory body should take into account potential contributions from present and foreseen sources, both global and regional, other than the plant under consideration, and should leave an appropriate margin for unknown future exposures. The regulatory body should also consider the results achieved for plants of the same type at which relevant good practices have been adopted and — leaving a margin between those results and the dose constraint to allow for a degree of flexibility — it should establish authorized discharge limits for the plant concerned. Improvements in the effluent control process at the plant in question may well lead to lower levels of discharges than the authorized discharge limits. Such a lower level may in turn be used by the regulatory body in the authorization of discharges, in particular as a reference level to indicate any deviation from anticipated operating conditions. The use of a lower level of discharges as a reference level should not compromise operational flexibility, nor should operators be discouraged from making improvements in the effluent control process in order to reduce discharges.

Investigation levels

2.26. Investigation levels should be seen as important tools for use by management in optimization of the protection of workers and the public, and should therefore be defined at the planning stage of activities. They may be revised on the basis of operational experience. Regulatory bodies may also wish to establish generic investigation levels. An investigation level is defined as “the value of a quantity such as effective dose, intake or contamination per unit area or volume at or above which an investigation should be conducted”. Investigation levels should be used in a retrospective sense and should not be confused with dose limits or dose constraints.

2.27. The exceeding of an investigation level should prompt a review of its circumstances to determine the causes. Appropriate lessons for future operations should be derived and any necessary additional measures should be taken to improve the current arrangements for protection.

2.28. Management should assign in advance to suitably qualified and experienced persons the responsibility for initiating and performing investigations when necessary. The purpose of, and the actions associated with, each investigation level should also be clearly defined in advance.

Structure and commitment of management

2.29. The proper application of the principle of optimization of protection requires that the operating organization put in place a management structure to ensure that radiation protection is appropriately considered at all levels of the operating organization.

2.30. The requirements for optimization at all stages of the operation of a plant should be reflected in programmes for radiation protection and for radioactive waste management. In addition, the management's policy statement may set targets such as a target for work to be performed with specified goals (in terms of doses, person-hours, time). These goals should be communicated to all site workers, together with evidence of the management's commitment to them. Guidance on the optimization of occupational radiation protection is given in Refs [6, 10].

2.31. The operating organization should encourage site personnel to maintain a questioning and learning attitude to protection and safety, should strengthen lines of communication and should discourage complacency by means of a safety policy implemented at the plant (Ref. [2], para. 2.28). Such an attitude on the part of staff, encouraged by fostering a safety culture, enhances and supports the safety actions and interactions of managers, supervisors and personnel involved in activities bearing on the safety of the plant. Workers should also be committed and should be motivated to adopt good practices in radiation protection and radioactive waste management. The operating organization should ensure that mechanisms are in place to involve workers, to the extent possible, in the development of methods to keep doses to site personnel and the public as low as reasonably achievable, and to provide for feedback on the effectiveness of measures for radiation protection and radioactive waste management.

2.32. As with any such initiative, success will depend upon motivation and on support at the highest levels of management of the operating organization. The management should be willing to support, in terms of policy and budget, efforts to keep doses to workers and the public as low as reasonably achievable.

2.33. Commitment on the part of management is demonstrated by its effective presence. Management policy should be: to encourage managers to make frequent visits to the work site(s); to have first hand knowledge of the status of projects and of problems; to encourage desirable practices; and to provide training if undesirable practices are found, or retraining if technological processes or equipment are modified or changed.

PROGRAMMES AND ORGANIZATIONAL ASPECTS

2.34. The regulatory body should give directives to the operating organization to establish and implement programmes to meet the requirements for radiation protection and radioactive waste management established in Section 8 (paras 8.1–8.12) of Ref. [1]. The regulatory body is required under Section 3 of Ref. [12] to ensure that its regulatory principles and criteria are adequate and valid, and to take into consideration internationally endorsed standards and recommendations. The regulatory body is also required to provide for issuing, amending, suspending or revoking authorizations, subject to any necessary conditions, which specify among other things the facilities, activities or inventories of sources that they cover. The regulatory body is required to carry out regulatory inspections, by means of which it should check that its principles and criteria and any necessary conditions of authorization have been complied with. For details of the responsibilities and functions of the regulatory body, see Ref. [12].

2.35. All applicable recommendations of the regulatory body and the existing national legal provisions should, wherever practicable, be translated into specific provisions and procedures that individuals can apply, and should be incorporated into the radiation protection programme (RPP) and radioactive waste management programme (RWMP) of the plant.

2.36. In developing these programmes, the operating organization should ensure that the resources allocated to them are commensurate with the nature of the radiological risks presented by the tasks to be performed.

2.37. Generally in the nuclear industry, circumstances vary so much that a structured approach to the RPP and the RWMP should be adopted in which the objectives are stated and the specific organizational structures, procedures and tools necessary for application of the ALARA principle are specified.

2.38. In accordance with Refs [2, 7], the management of the operating organization should be responsible for ensuring that appropriate radiation protection programmes are set up and implemented. Details on the assignment of responsibilities are given in Section 3.

2.39. The operating organization is required to ensure that suitable and adequate human resources are provided to oversee the implementation of the RPP and RWMP (Ref. [2], para. I.4 (h)). For this purpose, the operating organization should clearly specify relevant responsibilities. It should consider appointing a radiation protection officer (radiation protection manager). The radiation protection officer should be independent of the production, operation and maintenance groups, and should be in a position to advise the plant management on the effectiveness of the RPP and the RWMP. The radiation protection officer should also have access to those managers who have the authority to establish and enforce appropriate procedures for the safe performance of work.

2.40. The duties and responsibilities of a radiation protection group may vary widely, depending on the organizational structure of the operating organization and on national practices. The radiation protection group is not usually responsible for implementing the RPP but for giving advice on radiological issues, confirming work permits and providing services such as radiological monitoring and training.

2.41. All site personnel are responsible for practising measures to control radiation exposure. Consequently, the operating organization is required to ensure that appropriate training in protection and safety is provided, as well as periodic retraining and updating, as required, in order to ensure that the necessary level of competence is maintained (Ref. [2], para. I.4 (h)). Requirements on the qualification and training of personnel performing duties that may affect safety are given in Section 3 of Ref. [1]. Recommendations on training are given in Section 5 of this Safety Guide.

2.42. In applying the principle of optimization of protection in work planning, there should be no difference in the emphasis on protection between permanent and temporary site personnel and contractors. In addition, even if another organization is the employer, responsibility remains with the plant operating organization to comply with the limits. For this purpose, appropriate records of previous doses received by these employees should be obtained and the dose not to be exceeded by each individual employed at the site should be specified. The operating organization "shall provide both the worker and the worker's employer with the relevant exposure records" (Ref. [2], para. I.45).

2.43. The RWMP should be implemented effectively so as to ensure that the resultant radioactive waste meets the requirements for handling, transport, storage and disposal, as given in the applicable national regulations, and international requirements and recommendations. In order to be able to execute the RWMP, the availability of, and ready access to, funds for managing the radioactive waste from a nuclear power plant, including funds for waste disposal in the future, should be ensured.

2.44. Abnormal occurrences in systems for the management of radioactive waste may have a potential for significant radiological consequences; the probability of such occurrences should be minimized by reliable operation of the processing facilities. The operating organization should be responsible for ensuring the effective management of all activities relating to the operation and maintenance of such systems. This includes the provision of procedures and proper measures for supervision, training and quality assurance.

QUALITY ASSURANCE

2.45. The operating organization should have the primary responsibility for establishing and implementing an effective quality assurance programme, with a graded approach, covering all work associated with radiation protection and waste management that bears on the safe operation of the plant (Ref. [1], para. 2.19). These programmes should include requirements for quality assurance in radiation protection and in radioactive waste management. The extent and type of the specific requirements should reflect the safety significance and the nature of the individual tasks. The quality assurance programme is subject to the requirements and recommendations of the Code and Safety Guides Q1–Q14 on Quality Assurance for Safety in Nuclear Power Plants and Other Nuclear Installations [13], and details of it should be made available to the regulatory body.

2.46. In accordance with the Code [13], the quality assurance programme should provide for the systematic assessment of its effectiveness. A specific assessment should be considered if modifications important to safety are introduced, new regulatory requirements become applicable or incidents or accidents occur.

INCIDENTS AND EMERGENCIES

2.47. The operating organization is responsible for making arrangements to deal with emergencies involving non-routine situations or events that necessitate prompt action to prevent or mitigate hazards or adverse impacts on human health and safety, the quality of life, property or the environment. This includes situations for which prompt action is warranted to mitigate the impacts of a perceived hazard. Adequate provision should be made for this in the RPPs. In particular, incidents and emergencies should be investigated to determine their causes in order to take measures to prevent a recurrence.

2.48. Despite all the precautions taken in the design and operation of a nuclear power plant, it remains possible for failures to occur or conditions to arise which may potentially lead to an emergency. Significant radioactive releases or significant exposures of workers or the public may potentially occur as a consequence of the operation of the plant or the transport of radioactive material. The operating organization and off-site officials (response organizations) are required to be prepared for potential emergencies on and off the site, including emergencies associated with the transport of radioactive material [14]. Emergency preparations should include:

(a) clearly defined responsibilities and authorities on and off the site;
(b) criteria for executing emergency plans and taking protective actions and criteria for terminating such actions;
(c) provisions for determining whether environmental contamination warrants the taking of protective actions, with monitoring capabilities and operational intervention levels that are consistent with international standards [2];
(d) provision for co-ordinated public information from an official source following an emergency bearing on public risks and actions;
(e) established and tested emergency procedures;
(f) provision of adequate resources (such as facilities, equipment and staff);
(g) emergency response training, including exercises;
(h) methods and procedures for notification of the regulatory body and activation of response organizations;
(i) methods for the mitigation of emergencies;
(j) emergency communications both in the plant and with off-site emergency teams;
(k) medical, fire fighting and police assistance;
(l) protection of people on and off the site;
(m) protection for on-site and off-site personnel designated to respond to emergecies;
(n) provision of prior information to members of the public for whom it could reasonably be expected to be useful in an emergency;
(o) recovery, re-entry and post-accident operations.

2.49 The operating organization should prepare for potential emergencies on the site. The operating organization should provide off-site officials with the information necessary to prepare for potential emergencies off the site, including emergencies associated with the transport of radioactive material.

2.50. Requirements and guidance concerning preparedness for emergencies at nuclear power plants are given in Refs [14–17].

3. RADIATION PROTECTION PROGRAMME

GENERAL

3.1. The nature and intensity of sources of radiation deriving from the operation of a nuclear power plant will depend on various factors, including the type of reactor, its design features and its operational history. The protection of workers from harmful effects of radiation should be ensured by means of an RPP established by the operating organization.

3.2. The RPP should be based on a prior risk assessment in which the locations and magnitudes of all radiation hazards have been taken into account, and should cover:

(a) the classification of working areas and access control;
(b) local rules and supervision of work;
(c) monitoring of individuals and the workplace;
(d) work planning and work permits;
(e) protective clothing and protective equipment;
(f) facilities, shielding and equipment;
(g) health surveillance;
(h) application of the principle of optimization of protection;
(i) removal or reduction in intensity of sources of radiation;
(j) training (see Section 5);
(k) arrangements for the response to an emergency.

Further guidance on RPPs is given in Ref. [6].

CLASSIFICATION OF WORKING AREAS AND ACCESS CONTROL

3.3. The operating organization “shall designate as a controlled area any area in which specific protective measures or 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.” (Ref. [2], para. I.21.)

Paragraph 8.2 of Ref. [1] requires that the RPP cover the classification of areas and access control, including local information on actual dose rates and contamination levels. The regulatory body may issue guidance on the classification of controlled areas on the basis of the particular circumstances.

3.4. In determining the boundaries of any controlled area, the magnitude of expected doses in normal operation, the likelihood and magnitude of potential exposures, and the nature and extent of the required protection and safety procedures, including the control of radioactive waste, should be taken into account.

3.5. Controlled areas are required to be delineated and entry to them is required to be restricted (Ref. [2], para. I.23). The demarcation of controlled areas should utilize existing structural boundaries where practicable, provided that the radiological conditions meet the relevant requirements. The operating organization may extend the boundary of the controlled area as far as is considered necessary and practicable. One reason for doing this is to minimize the number of controlled areas and the number of access points to the controlled areas, thereby facilitating effective management of the RPP. Another reason is to make use of natural and other existing physical boundaries.

3.6. In some parts of a controlled area, compliance with the relevant limits can be achieved only by limiting the time spent there or by using special protective equipment. The definition of different zones within a controlled area, on the basis of dose rates or levels of loose contamination, should be considered. Some zones will necessitate setting conditions for restricted entry and special entry. Administrative control of entry into these zones can be effected by means of local rules or radiation work permits (see paras 3.39–3.47).

3.7. Since established practices, experience, plant design and other aspects may differ widely, the classification of radiological zones may also differ. An example of a zone classification scheme is given in Annex I.

3.8. Warning symbols such as those recommended by the International Organization for Standardization (ISO) and appropriate information (such as radiation levels or contamination levels, the category of the zone, entry procedures or restrictions on access time, emergency procedures and contacts in an emergency) are required to be displayed at access points to controlled areas and specified zones and at other appropriate locations within the controlled area (Ref. [2], para. I.23). Persons crossing a zone boundary should be made aware immediately that they have entered another zone in which dose rates or contamination levels, and thus the working conditions, are different.

3.9. Access to a controlled area is required to be restricted (Ref. [2], para. I.23) and should be restricted by way of a limited number of checkpoints in order to limit the spread of any contamination and to facilitate control at any time of exposure and occupancy. Procedures should be established for control of access to a controlled area or to a particular zone. These should include an authorization to enter, together with instructions on the use of monitoring devices, the wearing of specified protective clothing and equipment, and time limits for remaining on the premises.

3.10. Site personnel (permanent and temporary plant staff and contractor personnel) who enter controlled areas are required to be duly authorized in accordance with established administrative procedures (Ref. [2], para. I.23) and recommendations on radiation protection and on training. Authorization for entry may be granted for the entire controlled area or for a limited part of it. The authorization may expire at a specified time or it may be withdrawn if radiological conditions change. Special permission to enter a controlled area may be granted to persons who are not authorized in compliance with the recommendations on radiation protection, provided that they comply with a written system of work procedures which includes being accompanied at all times by an authorized escort.

3.11. Changing areas shall be provided, as appropriate, at the entrances to and exits from those zones which are contaminated or may become contaminated (Ref. [2], para. I.23). Changing areas should be designed to prevent the spread of contamination by means of partition into a clean side and a potentially contaminated side. The facilities that should be provided are specified in paras 3.56–3.60.

3.12. Equipment is required to be provided, as appropriate, for the monitoring of persons at exits from controlled areas in order to ensure that contamination levels on their clothing and body surfaces are below a specified level (Ref. [2], para. I.23). However, when decontamination to the specified level cannot be achieved in the controlled area and special decontamination measures are necessary, or when medical attention is necessary, departure should be in accordance with established procedures.

3.13. Before items are removed from any contamination zone, and in any case before they are removed from controlled areas, they are required to be monitored as appropriate (Ref. [2], para. I.23) and suitable measures should be taken to avoid undue radiation hazards.

3.14. The operating organization “shall designate as a supervised area any area not already designated as a controlled area but where occupational exposure conditions need to be kept under review even though specific protection measures and safety provisions are not normally needed” (Ref. [2], para. I.24). Supervised areas should be delineated by appropriate means, with account taken of the nature and extent of the radiation hazards. Approved signs should be displayed at appropriate access points, and the conditions should be periodically reviewed to determine whether there is any need for protective measures and safety provisions or for changes to the boundaries of the supervised areas.

3.15. Extension of the outer boundary of a supervised area to the site fence so as to facilitate effective management of the RPP should be considered.

LOCAL RULES AND SUPERVISION OF WORK

3.16. The operating organization “shall establish occupational protection and safety measures, including local rules and procedures that are appropriate for controlled areas” (Ref. [2], para. I.23). The local rules should include:

(a) a specification and location for each controlled area;
(b) procedures for access to and exit from controlled areas;
(c) procedures for ensuring adequate levels of protection and safety for workers and other persons, which should include the conditions under which visitors, pregnant or breast feeding women, and workers who are not radiation workers may enter controlled areas;
(d) the values of any relevant investigation level or authorization level and the procedures to be followed if the level is exceeded;
(e) designation of persons who are responsible for supervising work within controlled areas;
(f) emergency procedures for each controlled area.

3.17. Persons should not be appointed to supervise work in controlled areas unless they know and understand the requirements for radiation protection and the local rules, in so far as these apply to the work to be supervised.

3.18. All workers should be made aware of the local rules before they enter any controlled area and copies of the local rules should be properly displayed in the workplace.

WORKPLACE MONITORING AND INDIVIDUAL MONITORING

3.19. Three types of workplace monitoring and individual monitoring should be conducted for radiation protection purposes:

(a) routine monitoring should be conducted to demonstrate that the working environment is satisfactory for continued operations and that no change has taken place that would call for a reassessment of operational procedures;
(b) task related monitoring should generally be conducted to supply information about a particular task or operation and to provide, if necessary, a basis for immediate decisions on the execution of the task;
(c) special monitoring should normally be undertaken at the commissioning stage for new facilities, following major modifications to either facilities or procedures, or when operations are being carried out under abnormal circumstances such as those following an incident or an accident.

3.20. Investigation levels for individual doses and intakes should be set by the management on the basis of expected levels of individual dose. Investigation levels for workplace monitoring should be set on the basis of the expected levels of dose rate and contamination and operational experience. The purpose of, and the actions associated with, each investigation level should be clearly defined in advance. Investigation levels may be revised as necessary on the basis of operational experience.

3.21. Details of monitoring programmes for workers are given in the Safety Guide on Occupational Radiation Protection [6]. Guidance on dose assessment for external and internal exposure is given in the Safety Guides on Assessment of Occupational Exposure Due to External Sources of Radiation [18] and on Assessment of Occupational Exposure Due to Intakes of Radionuclides [19].

3.22. An appropriate service for calibration and quality assurance should be provided for all monitoring instruments used in the plant and included in the RPP. The service should ensure traceability to national standards laboratories. The instruments available should cover measuring ranges that extend from below any applicable reference level up to radiation levels anticipated to prevail under accident conditions.

3.23. All radiation monitors and contamination monitors, both permanently installed and hand held, as well as personal dosimetry systems, should be periodically calibrated, tested and maintained according to a quality assurance programme in respect of:

(a) quality of equipment and instruments;
(b) frequency of calibration;

(c) frequency of maintenance;
(d) traceability of usage.

Reviews and audits should be performed on all quality related activities.

Workplace monitoring and surveys

3.24. The main objectives of radiological monitoring and surveying are: to provide information about the radiological conditions at the plant and in specific areas before and during a task; to ensure that the zone designation remains valid; and to determine whether the levels of radiation and contamination are suitable for continued work in the zone.

3.25. This surveillance should be performed by means of an appropriate combination of fixed monitors for radiation and air contamination and through periodic monitoring and sampling by trained personnel. Since radiological conditions are rarely uniform throughout an area, the locations of fixed monitors for use in assessing ambient radiological conditions should be given careful consideration. Wherever fixed monitors are provided, they should be located where major or rapid changes in radiation levels, dose rates or levels of air contamination (caused by gases, iodine or particulates) may occur, and should incorporate alarms that indicate if a reference level has been exceeded. In areas where frequent occupancy is expected, consideration should be given to providing fixed monitors.

3.26. The frequency of monitoring and surveys as well as the types and locations of the measurements to be performed should be designated on radiological surveillance forms as part of the RPP and updated as necessary in accordance with the prevailing conditions.

3.27. Special surveys may be undertaken to meet specific problems, for example, if high levels of airborne contamination or loose surface contamination are suspected, or when routine monitoring reveals unusual or abnormal conditions such as the occurrence of an area of elevated activity (also called a hot spot).

3.28. The operating organization should ensure that equipment necessary for the RPP is provided, including various instruments for measuring radiation and for sampling and analysis. The quantities and types of equipment provided should be adequate for anticipated needs in normal operations and emergencies, and account should be taken of radiological conditions prevailing and suspected or expected to prevail in the local area.

3.29. The equipment to be provided for measuring radiation and activity and for sampling and analysis may include:

(a) counting instruments and shields for measuring activity and for the analysis of radioactive materials;
(b) instruments for radiation surveying and monitoring, including those for environmental monitoring;
(c) fixed instruments for monitoring external radiation, airborne contamination and process activity;
(d) personnel monitoring instruments, including:
    (i) personnel monitoring dosimeters (some with dose rate or dose alarm devices);
    (ii) contamination monitors, such as portal monitors and hand and shoe monitors;
    (iii) portable monitors;
(e) air samplers;
(f) radiation sources, instruments and other devices necessary for the calibration of radiation measuring and radiation analytical instruments and air samplers.

3.30. While the individual exposure of a worker is normally assessed by means of individual monitoring, it may be assessed by means of workplace monitoring subject to the approval of the regulatory body, as appropriate. It should be ensured that the monitoring information from fixed monitors and surveys that is selected is representative of radiological conditions in the area. Special precautions should be taken to obtain air samples that are indicative of the air contamination in the breathing zone. Workplace monitors for use in assessing individual doses or for confirming that certain levels are not exceeded should be specifically identified in order to prevent their unauthorized removal.

3.31. The reliability of the monitoring for the assessment of external and internal doses depends on many factors, including: functional testing; periodic maintenance and performance testing of the instruments used for these measurements; the calibration methods; and the qualification of the staff involved. Likewise, the traceability of these measurements and the retrievability of dose assessments should be given appropriate consideration. An adequate quality assurance system should be implemented so as to confirm the validity of the results of the assessment.

3.32. The operating organization should draw up a preventive maintenance schedule for all radiation monitoring systems. The performance of monitoring systems should be tested. Performance testing should always include calibration of the instrument and verification of the calibration facilities. These steps will ensure that doses are being assessed correctly, which in turn will enable the plant management to confirm the adequacy of controls exercised at workplaces.

Individual monitoring

3.33. "For any worker who is normally employed in a controlled area, or who occasionally works in a controlled area and may receive significant occupational exposure, individual monitoring shall be undertaken where appropriate, adequate and feasible. In cases where individual monitoring is inappropriate, inadequate or not feasible, the occupational exposure of the worker shall be assessed on the basis of the results of monitoring of the workplace and on information on the locations and durations of exposure of the worker" (Ref. [2], para. I.33). "The nature, frequency and precision of individual monitoring shall be determined with consideration of the magnitude and possible fluctuations of exposure levels and the likelihood and magnitude of potential exposures" (Ref. [2], para. I.35).

3.34. The assessment of individual external exposure is readily performed by individual monitoring. For routine monitoring, an integrating personal dosimeter should be worn. These dosimeters should be processed and the results evaluated at appropriate intervals by an approved monitoring service. Task related and special individual monitoring is normally performed by real time self-reading dosimeters, often with additional warning functions. Guidance is given in Ref. [18].

3.35. Whenever established procedures allow persons such as occasional visitors to enter a controlled area without individual monitoring dosimeters, it should be ensured that their doses can be estimated either on the basis of the dose rates and the time spent in the various areas or by referring to dosimeters worn by persons accompanying them. Individual monitoring of occasional visitors is also practised in some cases.

3.36. When it is known or suspected that an external exposure of an individual will be significantly non-uniform, additional dosimeters should be worn on the parts of the body concerned, if appropriate, particularly the hands.

3.37. Persons who work under conditions in which internal exposures may occur should be appropriately monitored. This monitoring should be performed on a routine or an occasional basis, depending on the particular working conditions. Internal contamination should be assessed, as far as possible, by the use of indirect measurements, such as by analysis of excreta or by whole or partial body counting. If, for the potential intake of radioactive material, it is not feasible to make any measurements immediately after the intake, other methods based on the calculation of intakes can be used to obtain an approximation. The results of workplace monitoring or special surveys as well as readings of personal air samplers may be useful. A more detailed evaluation of significant intakes initially indicated by simple on-site body counters may be performed by means of a more sophisticated whole body counter provided as a backup system off the site. Guidance is given in Ref. [19].

3.38. Records from individual monitoring are required to be made available to the regulatory body, to the individual concerned and to the physician or the supervisor of the health surveillance programme (Ref. [2], para. I.47).

WORK PLANNING AND WORK PERMITS

3.39. The planning of work to be undertaken in controlled areas where it is possible that levels of radiation or contamination may be significant is an important means of keeping doses as low as reasonably achievable and should be considered. The radiation protection group should take part in the planning of any activities that might entail significant doses and should advise on the conditions under which work can be undertaken in radiation zones and contamination zones.

3.40. Such work planning should include the provision of written procedures as appropriate. Matters that should be considered in the planning of work include:

(a) information on similar work completed previously;
(b) The intended starting time, the expected duration and the personnel resources necessary;
(c) the plant’s operational state (cold or hot shutdown, operation at full power or decreased power);
(d) other activities in the same area or in a remote area of the plant that may interfere with the work or may require the work to be conducted in a particular manner;
(e) the need for preparation for and assistance in operations (such as isolation of the process, construction of scaffolding or insulation work);
(f) the need for protective clothing and a listing of tools to be used;
(g) communication procedures for ensuring supervisory control and co-ordination;
(h) the handling of waste arising;
(i) requirements and recommendations for industrial safety in general.

3.41. Responsibilities with regard to interfaces between different working teams should be clearly identified. A responsible work supervisor should be designated who should ensure that all participants have received training, including training in radiation protection, as needed for the type of work and the conditions in which the work will be undertaken.

3.42. The work planning should ensure that personnel, tools, equipment and materials are available when needed, that a check for completeness is performed before the work is started and that standard instructions are established for measures to be taken in the event of abnormal situations. Training on mock-ups (see Section 5) should be considered.

3.43. Preparation of the work area may be necessary, for example by: cordoning it off and posting warning signs; laying down temporary coverings to retain contamination; and providing local changing areas for protective clothing, solid waste bins, additional radiation monitors, temporary radiation shielding or ventilation.

3.44. For tasks necessitating radiological precautions, a radiation work permit (RWP) should normally be prepared. A copy of the RWP should be submitted to the supervisor of the work and it should be retained with the work team throughout the performance of the work. Information and instructions that may be given in the RWP in addition to a description of the work would include for instance:

(a) details of average dose rates and possible areas of elevated activity in the working area on the basis of a survey made prior to the work or otherwise estimated;
(b) estimates of contamination levels and how they might change in the course of the work;
(c) additional dosimeters to be used by the workers;
(d) protective equipment to be used in different phases of the work;
(e) possible restrictions on working time and doses;
(f) instructions on when to contact members of the radiation protection group.

3.45. An authorized person of the operations group and a member of the radiation protection group should sign the RWP to confirm that if the specified precautions are taken the work described can be performed safely.

3.46. The person in charge of planning the operations should issue the RWP to the person who is to supervise or carry out the work. The person in charge of operations should sign the RWP to confirm that the workplace is in the condition specified in the permit. The RWP should be amended if necessary to take into account changing conditions as the work proceeds.

3.47. On completion of the task, the person who supervises or carries out the work should return the RWP to the person in charge of operations, thereby certifying that the work has been finished, that all personnel employed on the task have been withdrawn and that the workplace may safely be returned to its normal operating conditions.

PROTECTIVE CLOTHING AND PROTECTIVE EQUIPMENT

3.48. Protective clothing should be worn in controlled areas to prevent the contamination of skin and personal clothing and the spread of contamination from controlled areas. Gloves of various types and materials should be made available for use to prevent the contamination of hands in work involving contaminated equipment. Disposable or washable boots made of rubber or plastic should be used in the event of leaks onto the floor.

3.49. For certain tasks additional coveralls to be worn over the normal overalls should be provided. For physically demanding work or as protection from tritium hazards, stronger plastic suits, ventilated if necessary, should be made available. The suit may be pressurized by means of a supply of breathing quality air from a compressor or from pressurized air bottles.

3.50. In areas where airborne contamination or loose surface contamination is present or may be produced during work, use of respiratory protective equipment may be necessary and should be considered. The protective equipment should meet the specifications in the RWP and any administrative procedures should be complied with.

3.51. Respiratory protective equipment issued to an individual should protect suitably against the specific radionuclides of concern. The equipment should be especially selected to provide the degree of protection necessary with the objective of minimizing the total dose by using a predetermined set of protection factors as a guide.

3.52. The use of certain items of protective equipment may prolong the working time and thus increase the external dose received during the work. In deciding on the type of protective equipment to be used, it should be taken into account that in some cases protective equipment may thus cause the worker to receive an additional external dose that is greater than the internal dose averted by its use.

3.53. After use, protective clothing and respiratory equipment should be considered contaminated and should be handled accordingly.

3.54. Work in radiation zones and contamination zones may also necessitate the use of other types of special equipment for reducing doses, such as: portable shields;

portable ventilation equipment with filters for local exhaust; remote handling tools; special monitoring and communication equipment; special temporary containers for solid radioactive waste; and containers for radioactive liquids.

3.55. Site personnel, including contractor personnel, should be specifically trained and qualified in the use of protective clothing and special protective equipment, as appropriate. Those persons handling, issuing or decontaminating protective clothing and respiratory protective equipment should also be appropriately instructed.

FACILITIES, SHIELDING AND EQUIPMENT

3.56. The management should provide certain facilities that are necessary for effective radiological control in the operation and maintenance of the nuclear power plant and for responding to emergencies. The facilities should include:

(a) an operations office for radiation protection, a facility for instrument calibration and rooms for the preparation of samples and measurement of activity;
(b) a changing room for protective clothing with washing and showering facilities, a laundry for protective clothing, a personnel decontamination room and a first aid room;
(c) an equipment decontamination facility, a storage area for contaminated items and tools, a special workshop for maintenance of radioactive components and a store for radiation sources;
(d) appropriate facilities and instruments for the management, conditioning and storage of radioactive waste, and equipment for the handling and transport of radioactive waste of different types.

3.57. The plant should be equipped with radiation shielding materials of different types for temporary use in special jobs. Examples of such shielding materials are lead blankets (lead wool in flexible covers), sheets and bricks of lead, sheets of transparent perspex and blocks of concrete.

3.58. For the on-site transport of activated objects (such as in-core detectors or loose parts that have become activated in the reactor core), appropriate packaging for transport should be used. The packaging should have appropriate shielding and it should be clearly marked for use only for the on-site transport of activated objects.

3.59. In addition to the equipment for workplace monitoring and individual monitoring listed in para. 3.29, equipment for radiological control may include:

(a) miscellaneous supplies, such as movable shielding, signs, ropes, stands, sampling equipment and documents;
(b) emergency equipment, including self-powered air samplers and additional protective clothing (consideration should be given to providing emergency vehicles, boats, radios and other specialized equipment for use in an emergency);
(c) personal protective equipment, including protective clothing and respiratory protective equipment and a fresh supply of breathing air from a compressor;
(d) meteorological instruments.

3.60. Measures should be taken to ensure that the equipment is properly maintained.

HEALTH SURVEILLANCE

3.61. "Health surveillance programmes shall be:

(a) based on the general principles of occupational health; and
(b) designed to assess the initial and continuing fitness of workers for their intended tasks" (Ref. [2], para. I.43).

3.62. The operating organization "shall make arrangements for appropriate health surveillance in accordance with the rules established by the Regulatory Authority [regulatory body]" (Ref. [2], para. I.41). It should utilize the services of a physician who has been adequately trained in radiation protection and has the necessary understanding of the biological effects of radiation exposure and the risks associated with exposure, both in routine operations and as a consequence of an accident [6].

3.63. Following the initial medical examination, the need for and the nature of continuing surveillance of the health of individuals should be considered. The supervisor of the health surveillance programme should have access to all information concerning working conditions that may influence workers' health, and is required to have access to the dose records for each individual worker (Ref. [2], para. I.47). The supervisor of the health surveillance programme should also have access to information about changes in working conditions (such as revised job descriptions or revised descriptions of working environments) and information relevant to the state of health of individuals (such as details of absences due to sickness).

3.64. The supervisor of the health surveillance programme should be consulted on the use of protective clothing and respiratory equipment by personnel who wear such clothing or equipment for performing their duties.

3.65. In general, specific medical information about an individual is confidential. However, if an individual is not medically fit to perform his or her tasks, the physician should inform the management, as appropriate, in accordance with the recommendations of the regulatory body.

3.66. Further information can be found in a Safety Report on Health Surveillance of Persons Occupationally Exposed to Ionizing Radiation [20].

APPLICATION OF THE PRINCIPLE OF OPTIMIZATION OF PROTECTION

Objectives and tasks

3.67. For the control of radiation exposure of personnel, consideration of the optimization of radiation protection is required in the design and operation of a nucleasr power plant [1, 21] (see paras 2.14–2.33) in order to keep doses as low as reasonably achievable, economic and social factors being taken into account. In line with this requirement, in examining working procedures and activities, the reduction of doses should be given the highest priority. A hierarchy of control measures should be taken into account in optimization. Firstly, removal or reduction in intensity of the source of radiation should be considered. Only after this has been done should the use of engineering means to reduce doses be considered. The use of systems of work should then be considered and, lastly, the use of personal protective equipment. Methods of dose reduction that should be considered include:

(a) reducing radiation levels in work areas, for example, by the use of temporary shielding;
(b) reducing surface and airborne contamination;
(c) reducing working time in controlled areas;
(d) optimizing the number of workers in the work team;
(e) increasing the distance from the dominant radiation source;
(f) identifying low dose areas where workers can go without leaving the controlled area if their work is interrupted for a short time.

Experience from previous work should be taken into account.

3.68. Specifically, the RPP should state the objectives and specify the structures, as well as the procedures and tools, necessary for putting the programme into effect. These will generally include:

(a) setting the programme's goals and objectives, for example, targets for collective doses for the year, for outages and for specific tasks;

(b) specifying procedures for radiation protection (such as the co-ordination of outages and use of specific radiation protection work groups);
(c) assigning responsibilities and levels of authority, mindful of the fact that workers may be able to provide valuable input to the development and maintenance of the RPP;
(d) specifying working procedures and recommendations for the preparation, implementation and post-task analysis of operations (for example, techniques for exposure reduction, project reviews and pre-task briefings);
(e) providing the means to measure the success of efforts in radiation protection; for example, a monitoring system that provides timely, periodic feedback up and down the line of management on whether the programme's goals and objectives have been met;
(f) providing the measures necessary to take corrective action when information that has been fed back indicates failures and shortcomings in the programme.

Assignment of responsibilities

3.69. All workers and managers should be assigned the responsibility for applying the RPP within their own fields of activity. These responsibilities should be clearly delineated, particularly for the plant manager, department managers, radiation protection officer and/or manager, plant workers and contract workers.

3.70. Whereas the plant manager is responsible overall for activities, department managers are responsible for ensuring that work is performed in accordance with the principles and procedures of radiation protection. Furthermore, each individual is responsible for keeping his or her radiation doses as low as reasonably achievable by following training and procedures for radiation protection and by identifying to the management any opportunities to reduce doses.

3.71. The plant manager is responsible for implementation of the RPP in accordance with the policy and objectives of the operating organization. To this end the plant manager:

(a) participates in formulating the goals and objectives of the plant's RPP;
(b) supports plant personnel, particularly the radiation protection officer and/or manager, in terms of implementing radiation protection measures;
(c) ensures that there are open channels of communication to the corporate level;
(e) reviews the status of efforts to reduce exposure.

3.72. Department managers are responsible for implementation of the plant's RPP (also called the ALARA programme) for their field of activity. To this end they should:

(a) define the specific responsibilities of their department within this programme;
(b) validate and control the procedures and methods elaborated to achieve the objectives;
(c) support their personnel in the implementation of the RPP;
(d) periodically review the performances of their departments in terms of achieving the objectives of the plant's RPP.

3.73. The radiation protection officer and/or manager should have direct access to the highest level of plant management to resolve issues and to deal with concerns relating to radiation protection as necessary. The responsibilities of this position include:

(a) developing methods and procedures for implementation of the RPP;
(b) identifying conditions and operations that can cause significant exposure;
(c) transferring to other departments data received as feedback (such as radiological data or dose levels);
(d) implementing an initial training programme for radiation protection and providing continued input to the training programme.

3.74. Radiation protection personnel are responsible for following operations to ensure that radiation protection policies are implemented and that tasks are carried out in accordance with the ALARA principle. Their responsibilities should include:

(a) providing assistance and advice to workers to ensure that they know how to apply the ALARA principle in carrying out radiation work;
(b) following up operations to ensure that procedures for protection and safety are adhered to;
(c) stopping work in the event of serious deviations from dose targets or a significant increase in radiological risks for workers.

3.75. Finally, each worker should also have specific responsibilities, such as:

(a) putting into practice the exposure control measures specified in the RPP;
(b) identifying and suggesting improvements and good practices for the reduction of exposure wherever possible.

REDUCTION OF SOURCES OF RADIATION

3.76. In order to optimize the radiation protection of workers for all work in radiation areas, including maintenance, repairs, refuelling, plant modifications and in-service inspection, the RPP should include actions to eliminate unnecessary radioactive materials from the site.

3.77. The buildup of radioactive residues in piping and components of the primary system can be reduced by maintaining close control over the selection of materials and chemical parameters. In the design and the operation of the reactor, attention should be paid to ensuring that materials and chemical parameters are specified and controlled so as to minimize the production and buildup of radionuclides.

3.78. Efforts should be made to exclude extraneous materials, for example, chemicals, corrosion products and loose parts, from the primary system. Transport of corrosion products and precursors of activation products in the primary system should be controlled in order to reduce out-of-core radiation fields. Small parts such as welding rods, screws and nuts could be transported through the system, damaging components or fuel. In addition, such material, which may become activated by being caught up in the fuel for a period and then be released, could become a significant source of radiation.

3.79. In order to minimize the production of cobalt-60 due to neutron irradiation, cobalt should be removed from the primary system during the modification of piping systems and during maintenance where this is appropriate and feasible. Components such as valve seats and seat weld materials containing cobalt should be replaced to the extent possible with materials with no or low cobalt content.

3.80. Operating procedures used in plant shutdowns should be planned to reduce the likelihood of transients leading to a buildup of radioactive material, and corrosion products should be removed where this is feasible; for example, purification of the coolant should be considered.

4. PROGRAMME FOR RADIOACTIVE WASTE MANAGEMENT, INCLUDING CONTROL OF DISCHARGES

GENERAL

4.1. Gaseous, liquid and solid radioactive wastes are generated as by-products of the operation of nuclear power plants. The nature and the amounts of such waste will depend on: the type of reactor; specific design features; operating procedures and practices, including maintenance, refuelling and operational occurrences; the operational history of the plant; and the integrity of the fuel.

4.2. The operating organization should establish, as part of its overall strategic planning, a radioactive waste management programme (RWMP), as referred to in Section 2, which should include provision for:

(a) keeping the generation of radioactive waste to the minimum practicable, in terms of both activity and volume, by using suitable technology;
(b) reusing and recycling materials to the extent possible;
(c) classifying and segregating waste appropriately, and maintaining an accurate inventory for each radioactive waste stream, with account taken of the available options for clearance and disposal;
(d) collecting, characterizing and storing radioactive waste so that it is acceptably safe;
(e) providing adequate storage capacity for anticipated radioactive waste arisings;
(f) ensuring that radioactive waste can be retrieved at the end of the storage period;
(g) treating and conditioning radioactive waste in a way that is consistent with safe storage and disposal;
(h) handling and transporting radioactive waste safely;
(i) controlling effluent discharges to the environment;
(j) carrying out monitoring for compliance at source and in the environment;
(k) maintaining facilities and equipment for waste collection, processing and storage in order to ensure safe and reliable operation;
(l) monitoring the status of the containment for the radioactive waste in the storage location;
(m) monitoring changes in the characteristics of the radioactive waste, in particular if storage is continued for extended periods, by means of inspection and regular analysis;
(n) initiating, as necessary, research and development to improve existing methods for processing radioactive waste or to develop new methods, and to ensure that suitable methods are available for the retrieval of stored radioactive waste.

A robust quality assurance programme should be set up and appropriate records should be prepared and adequately maintained in compliance with the requirements of and recommendations on quality assurance (see paras 2.45 and 2.46 and Section 6).

GENERATION OF RADIOACTIVE WASTE

Gaseous radioactive waste

4.3. Although the sources of gaseous radioactive waste differ according to the type of reactor, possible sources include: leakage from the coolant, the moderator systems or the reactor itself; degasification systems for the coolant; condenser vacuum air ejectors or pumps; the exhaust from turbine gland seal systems; and activated or contaminated ventilated air. In all cases, spent fuel in storage or in handling operations is a potential source of gaseous radioactive waste.

4.4. The generation of gaseous radioactive waste should be kept to the minimum practicable by means of measures such as:

(a) operating the reactor so as to avoid fuel failures and optimizing the time period for which leaking fuel remains in the reactor core;
(b) reducing leakage from the pressure boundary for the primary coolant;
(c) keeping levels of coolant impurities as low as practicable;
(d) filtering gaseous effluents, as appropriate.

Maintenance activities should be carefully planned to reduce the possibility of leakage of gaseous waste. Measures to reduce discharges of gaseous radioactive waste from nuclear power plants are given in Annex II.

Liquid radioactive waste

4.5. The primary coolant in water cooled reactors and water from the fuel storage pools are major sources of liquid radioactive waste since some of their radioactive content may be transported to the liquid radioactive waste stream via process streams or leakages. Although the composition of the liquid radioactive waste may vary appreciably according to reactor type, contributions to the stream may derive from reactor coolant let-down, evaporator concentrates, equipment drains, floor drains, laundry waste, contaminated oil and waste arising from the decontamination and maintenance of facilities and equipment.

4.6. The generation of liquid radioactive waste should be kept to the minimum practicable by means of measures such as:

(a) the proper selection of reactor materials, for example, by avoiding materials containing cobalt (see para. 3.79);
(b) operating the reactor so as to avoid fuel failures and optimizing the time period for which leaking fuel remains in the reactor core;
(c) reducing leakage from the primary coolant system and other connected systems;
(d) chemical adjustment of the cooling system and avoidance of deposits;
(e) planning and performing maintenance work with due care and with particular emphasis on precautions to avoid the spread of contamination;

(f) taking precautions to avoid the contamination of equipment and rooms in order to reduce the need for decontamination;
(g) optimizing decontamination procedures;
(h) reducing the production of secondary waste by the appropriate selection of waste processing methods.

Measures to reduce discharges of liquid radioactive waste from nuclear power plants are given in Annex II.

Solid radioactive waste

4.7. Solid radioactive waste results from the operation and maintenance of the nuclear power plant and its associated processing systems for gaseous and liquid radioactive waste. The nature of such waste varies considerably from plant to plant, as do the associated levels of activity. Solid radioactive waste may consist of: spent ion exchange resins (both bead and powder); cartridge filters and pre-coat filter cake; particulate filters from ventilation systems; charcoal beds; tools; contaminated metal scrap; core components; debris from fuel assemblies or in-reactor components; and contaminated rags, clothing, paper and plastic.

4.8. The production of solid radioactive waste should be kept to the minimum practicable by minimizing the amounts of gaseous and liquid wastes generated, thereby reducing the amounts of processed waste, and by means of measures such as:

(a) careful planning and performance of maintenance work;
(b) careful control of the packaging and handling of radioactive materials;
(c) avoiding the generation of secondary radioactive waste, for example, by placing restrictions on taking packaging and other material into the controlled area;
(d) efficient operation of processing systems for gaseous and liquid radioactive waste;
(e) effective procedures for the control of contamination and the implementation of effective decontamination methods;
(f) good segregation practices, including clearance of materials, at points of waste generation;
(g) the reuse and recycle of materials wherever possible.

CLASSIFICATION AND SEGREGATION OF WASTE

4.9. The successful management of radioactive waste depends in part on adequate classification and segregation.

4.10. Information on the classification of waste can be found in IAEA Safety Series No. 111-G-1.1, Classification of Radioactive Waste [22], which distinguishes between high level waste (HLW), low and intermediate level waste (LILW) and waste that can be cleared from nuclear regulatory control. LILW is separated into short lived and long lived waste (see Annex III). This classification relates to the disposal of the radioactive waste. Operational waste from nuclear power plants typically falls into the category of short lived LILW if it cannot be cleared from nuclear regulatory control. Spent fuel would be HLW if declared as waste.

4.11. Further instructions on how to segregate wastes should be developed in accordance with needs at the facilities concerned. For the purposes of determining treatment, handling and storage arrangements, it is convenient to classify radioactive waste further on the basis of:

(a) its origin;
(b) its physical and chemical forms;
(c) the radionuclide content and the total activity and specific activity;
(d) the intended methods of processing, storage and disposal.

4.12. In addition, it should be borne in mind that certain types of radioactive waste necessitate special consideration, such as radioactive waste containing alpha emitting radionuclides, which could arise from failed fuel. Inflammable, pyrophoric, corrosive or other hazardous materials should also be given special attention. Care should be taken to avoid mixing waste of these types with shorter lived LILW.

4.13. Gaseous radioactive waste should be classified for treatment purposes into waste arising directly from the primary coolant systems of the reactor and waste arising from the ventilation of plant areas.

4.14. Liquid radioactive waste, which is mainly water based, should be classified for processing purposes according to its specific activity and its content of chemical substances. For instance, radioactive waste containing boric acid or organic matter may need special treatment. Non-aqueous radioactive waste such as oil should be segregated for separate treatment.

4.15. Solid radioactive waste should be classified according to its nature and activity; for instance, sludges, cartridge filters, contaminated equipment and components, ventilation filters and miscellaneous items (such as paper, plastic, towels) may be segregated in accordance with the type of treatment and conditioning process, such as compaction, incineration or immobilization.

4.16. The segregation of radioactive waste into appropriate categories should be carried out as near to the point of generation as practicable. The waste should be segregated in accordance with written procedures.

STORAGE AND CHARACTERIZATION OF RADIOACTIVE WASTE

4.17. The storage and characterization of radioactive waste may take place between and within any steps in radioactive waste management.

4.18. Sufficient storage capacity, possibly in a phased modular form, should be made available for all the radioactive waste generated at a plant in normal operation and in anticipated operational occurrences if the waste cannot be disposed of, discharged or cleared from nuclear regulatory control. In the design of storage facilities, account should be taken of the various characteristics of the waste, the possible need for its future retrieval and the potential consequences of any improper handling. Irradiated fuel assemblies contain by far the greatest quantity of radionuclides and represent potentially the greatest hazard. They are required to be stored in a manner that ensures subcriticality and the removal of residual heat in compliance with established requirements and recommendations (Ref. [5], para. 5.28).

4.19. A margin of storage capacity should always be available in anticipation of any unforeseen events, such as delays in dispatching the radioactive waste from the site or the need for repairs to the storage facility. In order to ensure suitable margins of storage capacity, the available storage capacity for radioactive waste should be carefully controlled by maintaining an inventory of waste and where necessary its location. For solid radioactive waste, in particular bulky items, full use should be made of the capacity of the store by means of appropriate emplacement or rearrangement of its contents.

4.20. Excessive accumulation of untreated and/or unconditioned radioactive waste may give rise to hazards and should be avoided if reasonably practicable by means of properly scheduled treatment and/or conditioning.

4.21. Containers for the storage of radioactive waste should be suitable for their contents and for the conditions likely to be encountered in storage in order that the integrity of the container can be maintained over the necessary storage period. If reasonably practicable, storage vessels, pipes and other plant components that provide containment for radioactive waste should have a further barrier (secondary containment) with sufficient capacity to accommodate safely any leaks or spills. Monitoring devices with alarms set at appropriate levels should be provided as necessary to ensure the detection, location and assessment of any leakage from the containment.

4.22. Waste should be characterized for all steps in radioactive waste management. The characterization process should include the measurement of physical and chemical parameters, the identification of radionuclides and the measurement of activity content. Such measurements are necessary for monitoring the history of the radioactive waste or waste packages through the stages of conditioning, storage and disposal and for maintaining records for the future. The input of radioactive waste to the pretreatment, treatment and conditioning processes should also be monitored in order to provide information on the performance of the plants concerned and to help in reducing the amounts of radioactive waste generated.

4.23. Dose rates and surface contamination for waste containers should be measured in accordance with established procedures. The levels of dose rate and surface contamination as measured should comply with the requirements established by the regulatory body.

PROCESSING OF RADIOACTIVE WASTE

4.24. Processing (pretreatment, treatment and conditioning) systems for radioactive waste should be operated and controlled in accordance with written procedures for normal operation as well as for anticipated operational occurrences. The design intent and the operational limits and conditions, including authorized discharge limits, clearance levels and the criteria for maintaining doses as low as reasonably achievable, should be taken into account in these procedures.

4.25. Waste processing systems should be designed, operated and maintained in accordance with a programme in which the operational modes of the plant such as startup, full power operation and outages are taken into consideration.

4.26. Radioactive waste should be processed as early as practicable in order to convert it into a passively safe state and to prevent its dispersal during storage and disposal.

4.27. Waste packages resulting from the conditioning of radioactive waste are subject to the applicable requirements for handling, transport, storage and disposal. In order to obtain the required product, all operations should be carried out in accordance with established procedures and subject to quality assurance requirements [13].

Gaseous waste

4.28. In the operation of treatment systems for gaseous radioactive waste, consideration should be given to: the amount of gas to be treated; the activity; the radionuclides contained in the gas; the concentrations of particulates; the chemical composition; the humidity; the toxicity; and the possible presence of corrosive or explosive substances.

4.29. Noble gases with short half-lives should be retained in hold-up tanks or other delay systems that allow the radionuclides to decay to an acceptable activity or activity concentration before discharge.

4.30. Particulate matter should be removed by appropriate means such as filtration. Parameters that are critical to the effective operation of the filtration system should be monitored.

4.31. Volatiles should be removed from gaseous radioactive waste, for example, by passing the gases through an adsorbing agent such as charcoal. Parameters which indicate the efficiencies of the filtering medium in the systems concerned and the need to replace the adsorbing materials should be monitored.

4.32. If necessary, personnel should wear appropriate protective clothing and breathing apparatus when testing, maintaining or replacing filters or adsorbing beds so as to minimize the inhalation of particulates accumulated on the filters or the structures.

4.33. If combustible material is present or explosive mixtures may be formed, suitable prevention and control measures to reduce potential hazards should be established and taken.

Liquid waste

4.34. In the operation of processing systems for liquid radioactive waste, the amounts of liquids to be treated, the radionuclides present, the activity, the concentrations of particulates, the chemical compositions, the toxicity and the possible presence of corrosive substances should be taken into consideration.

4.35. Input streams should be characterized, in particular for new facilities, either before liquid waste streams reach the processing plant or early in the processing activities. By this means, different types of waste can be segregated appropriately and, if various options are available, the most effective methods of processing can be adopted.

4.36. For the effective processing of liquid waste, the following practices should normally be adopted:

(a) When more than one means of processing liquid radioactive waste is available to the operator, the choice should be made on the basis of careful consideration of all factors, including occupational exposure, public exposure and the generation of secondary waste.
(b) Waste of higher activity should not be diluted with lower activity waste if it may be easier to provide containment and shielding for a small volume of higher activity waste.
(c) Radioactive waste with a higher content of dissolved or dispersed solids should not be mixed with radioactive waste with a lower content of such solids since this would complicate the processing of the latter. The chemical compatibility of different waste streams, and of the radioactive waste and the equipment, should be taken into consideration.
(d) If liquids are recycled after treatment and conditioning, attention should be paid to the possibility of chemical cross-contamination so as to avoid unnecessary processing.
(e) The possible incompatibility of radioactive waste with components of the treatment and conditioning plant (for example, due to the potential for corrosion or scaling of evaporators) should be taken into consideration and the chemical composition of the waste should be kept under strict control in its processing.
(f) If radioactive waste outside the normal range of composition is to be processed, consideration should be given to flushing the equipment before it is returned to normal duties.
(g) Strict in-plant control over all parameters relevant to proper waste processing should be maintained and recommendations for radiation protection should be observed.

4.37. For waste conditioning, a suitable matrix material, if any, and a suitable container should be used. The container should be properly filled, closed and labelled in order to produce a waste package suitable for handling, transport, storage and disposal.

Solid waste

4.38. Solid radioactive waste may be inhomogeneous. Special consideration should be given to representative sampling before processing so as to confirm compatibility with the intended process, and appropriate arrangements should be made for this as far as practicable. Arrangements should also be made for systematic control of the final products to verify compliance with established requirements and recommendations.

4.39. A great number of processes are available for producing acceptable waste packages. Such processes should be selected on the basis of the characteristics of the waste concerned, with due account taken of radioactive decay. If possible, processes with high volume reduction factors should be applied with the use of proven techniques such as compaction or incineration.

4.40. If the operating organization uses a mobile conditioning unit rather than a permanently installed plant, care should be taken to prevent unnecessary contamination in the connection and disconnection operations with mobile units.

TRANSPORT OF RADIOACTIVE WASTE

4.41. Radioactive waste may be processed at a nuclear power plant or at an off-site facility. Preference should be given to on-site waste management. In various cases, transport to off-site facilities is advantageous (for example, for incineration) or necessary (to a repository). Radioactive waste should be moved from a nuclear site to another installation or site only if its transport is authorized by the regulatory body.

4.42. The transport of radioactive waste, both domestically and internationally, is subject to the national and international modal regulations for the safe transport of radioactive materials. National and international modal transport regulations are generally based on the IAEA Regulations for the Safe Transport of Radioactive Material [23].

4.43. Planning for the transport of radioactive waste should be considered at an early stage in the development of a programme for radioactive waste management.

4.44. The means (road, rail, waterways or air) for the transport of radioactive waste should be considered at an early stage and its transport should comply with the appropriate regulations. The preparation of packages for the transport of radioactive waste should be carried out in accordance with written, approved operating procedures. Precautions should be taken in handling radioactive waste in a facility or on a site. The precautions to be taken will depend principally on the nature of the radioactive waste and on the prescribed specific requirements for packaging established by the regulatory body.

DISCHARGE CONTROL AND COMPLIANCE MONITORING

4.45. Prior to the commencement of operations, the operating organization should propose to the regulatory body levels for gaseous and liquid discharges. In proposing such levels it should be demonstrated that they will result in compliance with national regulations [2, 7]. The purpose of setting levels for discharges is to ensure that radiation doses to members of the public due to the discharges do not exceed a fraction of the dose limit for the public (the dose constraint) when applied to the critical group and that such doses are as low as reasonably achievable (see para. 2.25). The expected discharges for all operational states of the plant and if possible also for potential future changes in operations should be taken into account in setting the levels to be proposed for discharges.

4.46. As discussed in para. 2.13, the proposed discharge levels should be based on an assessment of their expected radiological impacts by means of predictive modelling. Expected doses to the most highly exposed individuals should be estimated. It may be necessary to establish by means of habit surveys which members of the public are potentially the most highly exposed as a result of the discharges (the critical group or groups in the population). Account should be taken of their location with respect to the plant, food consumption, sources of food and drinking water and any habits or practices that might give rise to higher than average exposure to radiation.

4.47. The regulatory body, after considering the submissions of the operating organization, should establish authorized discharge levels. All discharges should be within the discharge levels authorized by the regulatory body.

4.48. Compliance with authorized discharge levels should be demonstrated by means of monitoring at the source of the discharge and confirmed by measurement in the recipient environmental media (such as water or air). The monitoring may be by continuous measurement and/or by representative sampling and intermittent measurement, as appropriate. For intermittent discharges into water, the assessment should be made by means of representative sampling and measurement before and, if appropriate, during and after each discharge.

4.49. Provision should be made to enable the prompt detection of any abnormal discharge of radionuclides, and the identification and assay of radiologically significant radionuclides should be performed for both gaseous and liquid discharges.

4.50. If an authorized discharge level has been or may have been exceeded, the operating organization should investigate the case. The operating organization should:

(a) terminate the discharge and take corrective actions;
(b) estimate the amounts of radioactive substances released;
(c) record all relevant details;
(d) report promptly to the regulatory body in accordance with prescribed procedures;
(e) investigate and identify the causes of any non-compliance.

4.51. If necessary, emergency response actions should be initiated.

Source monitoring

4.52. Source monitoring refers to the measurement both of discharges and of the radiation field around the source itself. The design of the source monitoring programme should be such that it enables the verification of compliance with external exposure limits and discharge limits and criteria specified by the regulatory body. The monitoring of radioactive discharges may entail making measurements for specific radionuclides or gross activity measurements as appropriate. Measurements should normally be made before or at the point of release (for example, the stack for atmospheric discharges or the discharge pipeline for a liquid discharge). For batch discharges, the material for discharge is more appropriately characterized by the volume of the batch and the radionuclide composition of a sample taken at the reservoir from the homogenized batch prior to discharge.

4.53. For both airborne and liquid effluents, three types of measurements should be considered:

(a) on-line monitoring of discharges;
(b) continuous sampling and laboratory measurements of activity in the sample;
(c) intermittent sampling and laboratory measurements of activity concentrations in the sample.

The choice of sampling method and measurement procedures should depend on:

(a) the characteristics and amounts of discharged radionuclides and the sensitivity of the measurement system;
(b) the expected variation with time, if any, in the rate of discharge for the radionuclide(s);
(c) the possibility of unplanned discharges which require prompt detection and notification.

Environmental monitoring

4.54. An environmental monitoring programme should be implemented in accordance with the requirements of the regulatory body. A pre-operational programme should be implemented two to three years before the planned commissioning of the plant. This pre-operational programme should provide for the measurement of background radiation levels in the vicinity of the plant and their variation over and between the seasons. It should also provide the basis for the operational programme of environmental monitoring and should include the routine collection and radionuclide analyses of various samples, such as samples of vegetation, air, milk, water, sediment, fish and environmental media collected from several fixed and identified locations off the site.

4.55. The operational programme should be implemented as an extension of the pre-operational programme, with account taken of guidance given in Ref. [7]. The samples taken during the operational programme should be similar to those taken in the pre-operational programme, but they may be collected at different intervals (for example, milk may be sampled more frequently and sediment less frequently). The operational programme should be reviewed in the light of experience and it should be modified if necessary. The programme should be designed to provide information for the purposes of:

(a) confirming the adequacy of control over effluent discharges;
(b) correlating the results of environmental monitoring with data obtained from monitoring at the source of the discharges;
(c) checking the validity of environmental models used in establishing authorized limits;
(d) fostering public assurance;
(e) assessing trends in the concentrations of radionuclides in the environment.

MAINTENANCE OF FACILITIES AND EQUIPMENT

4.56. The operating organization should prepare and implement a schedule for maintenance, testing, surveillance and inspection of facilities and equipment for radioactive waste management that are important to safety, including civil structures used to store radioactive waste.

4.57. The standard and frequency of maintenance work should be such that the levels of reliability and effectiveness of the facilities and equipment remain in accordance with the design assumptions and intent. In general, the schedule should take into account:

(a) analysis of maintenance requirements on the basis of previous experience or other applicable data (such as manufacturers' recommendations);
(b) work planning in relation to the availability of skilled personnel, tools and materials (including spare items);
(c) the monitoring programme for radiation protection and industrial safety;
(d) the potential for a loss of containment.

4.58. The management of radioactive waste is subject, as appropriate, to the requirements for maintenance, testing, surveillance and inspection for the operation of a plant as set out in Section 6 of Ref. [1].

5. TRAINING

5.1. “Organizations engaged in activities important to safety shall ensure that there are sufficient numbers of adequately trained and authorized staff working in accordance with approved and validated procedures” (Ref. [24], Principle 6). The operating organization “shall ensure, for all workers engaged in activities that involve or could involve occupational exposure, that suitable and adequate human resources and appropriate training in protection and safety be provided, as well as periodic retraining and updating as required in order to ensure the necessary level of competence” (Ref. [2], para. I.4 (h)). The requirements for qualification and training of personnel as set out in Section 3 of Ref. [1] should be taken into account appropriately in the management of radioactive waste. A Safety Guide on Building Competence in Radiation Protection and the Safe Use of Radiation Sources [25] provides recommendations and guidance on training.

5.2. The operating organization is responsible for the recruitment and training of all personnel and for the definition of levels of competence necessary to carry out various duties. The regulatory body should provide guidance on qualification requirements for plant personnel and, where appropriate, should review and approve any proposals made by the operating organization [25]. Training should be provided so as to ensure that site personnel attain and maintain the necessary level of competence to perform their duties and for their level of responsibility. Furthermore, skills should be acquired in training so as to help personnel to work efficiently and to respond effectively to changing circumstances, and thus to reduce their radiation exposure.

5.3. The operating organization should make arrangements for all plant staff to be adequately trained and confirmed to be as proficient in measures for radiation protection as necessary for the duties that they will be expected to undertake and for the responsibilities allocated to them.

5.4. Training for workers should cover all topics relevant to the radiation task assignments and the potential risks. Those who need to work in zones of high radiation levels should be trained in their specific work activities so as to enable them to perform their duties in the minimum possible time, in keeping with the principle of optimization. This could include, for example, training on mock-ups, rehearsing the planned work and practising emergency actions.

5.5. Training measures should cover the following topics to a level of detail commensurate with the assigned tasks and responsibilities of the respective worker or supervisor:

(a) the main types of ionizing radiation and their effects;
(b) basic quantities and units in radiation protection;
(c) basic protection and safety procedures, including the effects of time, distance and shielding on reducing exposure;
(d) principles of radiation protection and radioactive waste management (concerning optimization of protection and safety, dose limitation and waste minimization);
(e) use of protective equipment such as shielding and protective clothing;
(f) use of survey meters and contamination monitors, and individual external and internal monitoring, including dose assessment;
(g) the potential risks associated with the operation of nuclear power plants;
(h) rules and procedures at the plant, especially specific task related issues;
(i) warning signs and alarm signals and information on appropriate actions to be taken;
(j) contamination control, decontamination and reduction of sources of radiation;
(k) responsibility to inform designated persons immediately in the event of any unforeseen occurrence entailing increased risks in relation to radiation;
(l) where appropriate, actions that should be taken in the event of a nuclear or radiological emergency or an accident in the transport of radioactive material;
(m) regulations for the safe transport of radioactive material on and off the site;
(n) criticality safety for nuclear fuel;
(o) behaviour in controlled areas.

5.6. Training should be provided so as to ensure that the required knowledge and skills are efficiently transferred. For example, this could be achieved by means of manuals and other written documents, lectures and discussions, demonstrations, instructions, exercises, training on mock-ups, on the job training and rehearsals of planned work.

5.7. Training on emergency procedures should be given periodically to ensure that all persons who would need to take action in an emergency know which actions to take. All site personnel should take part in periodic exercises that simulate radiation emergencies of various types. It may be advisable to include off-site personnel such as fire fighters, medical staff and police who would be required to come onto the site in the event of an emergency.

5.8. Individuals whose assignments are incidental to the use of radiation and who may spend only brief periods in areas where exposure is possible should be provided with relevant basic information. Such information should cover issues such as: relevant and applicable local rules; the response to radiation alarms; and basic protection and safety procedures, including the effects of time, distance and shielding on reducing exposure. The risks associated with such individuals' levels of exposure, the potential hazards to which they may be subjected and the directives that apply in relation to prohibited actions should also be covered.

5.9. The operating organization should ensure that any personnel of other organizations who are employed on the site, particularly personnel of the contractors, have received training adequate to enable them to perform their work so as to meet the required standards of safety and quality. Special arrangements should be made so that temporary personnel whose normal place of work is elsewhere can become familiar with the relevant safety rules relating to their task in the plant. In specific instances, a qualified individual may be provided as a full time escort for temporary personnel, in lieu of providing them with training.

5.10. Training should be repeated as often as necessary, and particularly after changes in the task or significant changes or modifications to equipment, procedures or policies at the plant, so as to ensure that the required level of competence is maintained and that the implications of the changes for radiation protection and radioactive waste management are understood. For this purpose, records should be kept to show what type of training each person has undergone and when. Training programmes should be updated at regular intervals. In updating training procedures, the operating organization should take into account new recommendations and feedback from inspections by the regulatory body, and operational feedback on events at the plant and from other relevant plants, as well as any feedback from workers on training needs.

5.11. Female workers who work in controlled areas should be provided with appropriate information on the radiological risks to a foetus or embryo and the importance of notifying any pregnancy.

6. RECORDS

GENERAL

6.1. The operating organization is responsible for fulfilling the requirements in respect of records and reports set out in Section 9 of Ref. [1]. It is responsible for the collection, storage and retrieval of records concerning matters important to safety and for keeping these records in order to maintain up to date information and historical information on important aspects of the RPP and the RWMP. This information should be retained for use in meeting the objectives of these programmes and in preparing reports by the operating organization for the regulatory body.

6.2. Records should be prepared and stored in such a manner that they are readily retrievable and can be understood at a later stage. They should be classified as requiring retention for the long term (such as records of personnel doses), the medium term (such as records of shipments of radioactive waste) or the short term (such as records of survey results for controlled areas). The minimum periods of time for their retention should be specified by the regulatory body. However, the operating organization should decide on storage periods beyond the minimum period required.

6.3. Records concerning matters important to safety should be stored in at least two separate places, so that important information could not be irreplaceably lost in the event of a fire or other incident.

DOSE ASSESSMENT, MEDICAL SURVEILLANCE AND RADIATION PROTECTION TRAINING

6.4. "Exposure records for each worker shall be preserved during the worker's working life and afterwards at least until the worker attains or would have attained the age of 75 years, and for not less than 30 years after the termination of the work involving occupational exposure" (Ref. [2], para. I.49). Exposure records should include data for all individuals: for plant staff as well as for contractors' staff. Results from analysis of excreta and possible overexposures should be recorded and stored as part of the records. Employers, registrants and licensees are required to (Ref. [2], para. I.47) provide for access by workers to information in records of their own exposures. Recommendations and guidance on records are given in Refs [6, 18, 19].

6.5. Health surveillance records should be stored according to national regulations or the recommendations of the regulatory body. The storage period should normally be on a time-scale similar to that for dose records.

6.6. Information on the radiation protection training a person has received and the corresponding dates should be recorded, stored and updated as necessary

RADIATION SURVEYS, INSTRUMENT CALIBRATION AND RADIATION WORK PERMITS

6.7. The results of radiation surveys and contamination surveys in the controlled area should be recorded and stored. Recommendations and guidance on radiation and contamination surveys are given in Refs [6, 18, 19].

6.8. All installed radiation monitors, hand held radiation meters and dosimetry equipment should be tested and calibrated according to an authorized programme. The results of the tests should be recorded so that the testing and repair history for each instrument can be retrieved. Records of tests and calibrations are required to be maintained (Ref. [2], para. 2.40).

6.9. All radiation work permits should be filed and stored.

WASTE MANAGEMENT AND RADIOACTIVE SOURCES

6.10. The regulatory body is required to take suitable steps to ensure that appropriate records relating to the safety of facilities or sites for the management of radioactive waste are retained and retrievable for an appropriate period of time (Ref. [12], para. 3.3 (8)). As-built drawings should be kept for all facilities associated with radioactive waste management. Records, including all relevant details, should be kept on radioactive waste, on waste packages and on the contents of waste stores. At any time during storage it should be possible to determine from the records the type, activity and characteristics of the waste stored in each specified location. Computer assisted programmes should be used for the continuous updating of the radionuclide inventory, with account taken of radioactive decay.

6.11. All shipments of radioactive material and dispatch of treated or untreated radioactive waste for processing or disposal should be documented and recorded, including the type and quantity of such waste, the type of packaging and the destination. Records should also be kept of radioactive sources stored and used at the plant. These records should be retained even after the waste or the sources have been disposed of.

6.12. Reports on any investigations into abnormal conditions or deficiencies, such as unplanned releases or spills, in the programme for radioactive waste management should be kept. In particular, records of contamination levels in structures and components of the plant should be maintained in order to facilitate decommissioning.

DISCHARGES AND ENVIRONMENTAL MONITORING

6.13. Details of all gaseous and liquid discharges, including estimates of any unmonitored discharges, should be recorded and stored. These data, together with meteorological records, transport models, habit surveys and metabolic data, will form the basis for dose calculations for the critical groups.

6.14. All results of analyses of environmental samples should be recorded and stored.

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Annex I

CLASSIFICATION OF ZONES IN A CONTROLLED AREA FOR NUCLEAR POWER PLANTS

I-1. The following is an example of how zones in a controlled area may be classified:

(a) Radiation zone 1: access is normally prohibited because of high levels of radiation or contamination, but may be permitted under certain conditions (such as reactor shutdown) as specified in the operating procedures.
(b) Radiation zone 2: compliance with the applicable dose limit for external exposure can be ensured only by restricting working time.
(c) Radiation zone 3: all other areas within the controlled area.
(d) Contamination zone: special protective measures are necessary, owing to actual or potential air contamination or loose surface contamination in excess of a specified level. Subdivisions may be considered on the basis of the levels of precautions necessary in different areas of this zone.

Annex II

MEASURES TO REDUCE DISCHARGES OF GASEOUS AND LIQUID RADIOACTIVE WASTE FROM NUCLEAR POWER PLANTS

II-1. There are three general ways to reduce the amounts of radioactive substances released to the environment from nuclear power plants:

— keeping the source to the minimum activity practicable;
— holding up the liquids and/or gases to permit radioactive substances to decay;
— separating the radioactive material from the liquid and/or gas in order to allow it to decay or to transform it into solid waste.

MINIMIZING SOURCE ACTIVITY

II-2. In order to minimize the activity of the source:

— Establish good procedures in order to prevent leakage from fuel elements and primary systems.
— Plan and/or optimize the total handling of liquids in the plant (including pool water and pipe flushing) with the aim of reducing the amounts of liquid waste collected.
— Segregate liquids so as to avoid dilution and the mixing of chemically incompatible substances.
— Reduce the amounts of chemicals; recycle chemical substances whenever possible or use chemicals that can readily be made to decompose.
— Reduce the amount of active gas introduced into the systems to the minimum practicable (such as by using fresh inactive steam instead of primary active steam in the gland seal system in the turbine of a boiling water reactor).

LIQUID WASTE

II-3. In order to reduce liquid waste:

— use filters of different kinds to separate undissolved radioactive substances from the liquids;
— use ion exchange resins, more or less specialized for the purpose, and use standard methods to separate dissolved radioactive substances from the liquids;
— use evaporators to separate both dissolved and undissolved substances from the liquid;

— use hold-up tanks to allow radioactive material to decay before its release.

GASEOUS WASTE

II-4. In order to reduce gaseous waste:

— use filters for separating aerosols or iodine from the gaseous discharges;
— use delaying systems (charcoal beds, tanks) to allow the radioactive materials in the gases to decay;
— use treatments for volume reduction (such as those using recombiners, absorbers and pressurized storage) which may also function as a delaying system.

Annex III

TYPICAL CHARACTERISTICS OF WASTE CLASSES

Excerpted from Classification of Radioactive Waste,
IAEA Safety Series No. 111-G-1.1, IAEA, Vienna (1994)

Waste classes	Typical characteristics	Disposal options
1. Exempt waste (EW)	Activity levels at or below clearance levels on the basis of an annual dose to members of the public of less than 0.01 mSv	No radiological restrictions
2. Low and intermediate level waste (LILW)	Activity levels above clearance levels and thermal power below about 2 kW/m^3	
2.1. Short lived waste (LILW-SL)	Concentrations of restricted long lived radionuclides (limitation of long lived alpha emitting radionuclides to 4000 Bq/g in individual waste packages and to an overall average of 400 Bq/g per waste package)	Near surface or geological disposal facility
2.2. Long lived waste (LILW-LL)	Concentrations of long lived radionuclides exceeding limitations for short lived waste	Geological disposal facility
3. High level waste (HLW)	Thermal power above about 2 kW/m^3 and concentrations of long lived radionuclides exceeding limitations for short lived waste	Geological disposal facility

GLOSSARY

authorized discharge. Discharge in accordance with an authorization.

clearance. Removal of radioactive materials or radioactive objects within authorized practices from any further regulatory control by the regulatory body.

collective dose. The total radiation dose incurred by a population.

conditioning, waste. Those operations that produce a waste package suitable for handling, transport, storage and/or disposal. Conditioning may include the conversion of the waste to a solid waste form, enclosure of the waste in containers and, if necessary, providing an overpack.

container, waste. The vessel into which the waste form is placed for handling, transport, storage and/or eventual disposal; also the outer barrier protecting the waste from external intrusions.

contamination zone. A zone in which special protective measures are necessary, owing to actual or potential air contamination or loose surface contamination in excess of a specified level.

critical group. A group of members of the public which is reasonably homogeneous with respect to its exposure for a given radiation source and given exposure pathway and is typical of individuals receiving the highest effective dose or equivalent dose (as applicable) by the given exposure pathway from the given source.

disposal. Emplacement of waste in an appropriate facility without the intention of retrieval.

immobilization, waste. Conversion of waste into a waste form by solidification, embedding or encapsulation.

investigation level. The value of a quantity such as effective dose, intake or contamination per unit area or volume at or above which an investigation should be conducted.

monitoring. The measurement of dose or contamination for reasons related to the assessment or control of exposure to radiation or radioactive substances, and the interpretation of the results.

normal operation. Operation within specified operational limits and conditions.

occupational exposure. All exposure of workers incurred in the course of their work, with the exception of excluded exposures and exposures from exempt practices or exempt sources.

optimization. The process of determining what level of protection and safety makes exposures, and the probability and magnitude of potential exposures, "as low as reasonably achievable, economic and social factors being taken into account" (ALARA), as required by the ICRP System of Radiological Protection.

package, waste. The product of conditioning that includes the waste form and any container(s) and internal barriers (e.g. absorbing materials and liner), as prepared in accordance with requirements for handling, transport, storage and/or disposal.

packaging, waste. Preparation of radioactive waste for safe handling, transport, storage and/or disposal by means of enclosing it in a suitable container.

potential exposure. Exposure that is not expected to be delivered with certainty but that may result from an accident at a source or owing to an event or sequence of events of a probabilistic nature, including equipment failures and operating errors.

practice. Any human activity that introduces additional sources of exposure or exposure pathways or extends exposure to additional people or modifies the network of exposure pathways from existing sources, so as to increase the exposure or the likelihood of exposure of people or the number of people exposed.

processing, waste. Any operation that changes the characteristics of waste, including pretreatment, treatment and conditioning.

public exposure. Exposure incurred by members of the public from radiation sources, excluding any occupational or medical exposure and the normal local natural background radiation but including exposure from authorized sources and practices and from intervention situations.

radiation protection officer. An individual technically competent in radiation protection matters relevant for a given type of practice who is designated by the registrant or licensee to oversee the application of the requirements of the Basic Safety Standards.

reference level. An action level, intervention level, investigation level or recording level.

regulatory body. An authority or a system of authorities designated by the government of a State as having legal authority for conducting the regulatory process, including issuing authorizations, and thereby regulating nuclear, radiation, radioactive waste and transport safety.

segregation, waste. An activity where waste or materials (radioactive or exempt) are separated or are kept separate according to radiological, chemical and/or physical properties which will facilitate waste handling and/or processing.

site personnel. All persons working in the site area of an authorized facility, either permanently or temporarily.

spent fuel. Nuclear fuel removed from a reactor following irradiation, which is no longer usable in its present form because of depletion of fissile material, poison build-up or radiation damage.

storage. The holding of spent fuel or of radioactive waste in a facility that provides for its containment, with the intention of retrieval.

waste characterization. Determination of the physical, chemical and radiological properties of the waste to establish the need for further adjustment, treatment, conditioning, or its suitability for further handling, processing, storage or disposal.

waste management, radioactive. All administrative and operational activities involved in the handling, pretreatment, treatment, conditioning, transport, storage and disposal of radioactive waste.

waste, radioactive. For legal and regulatory purposes, waste that contains or is contaminated with radionuclides at concentrations or activities greater than clearance levels as established by the regulatory body.

worker. Any person who works, whether full time, part time or temporarily, for an employer and who has recognized rights and duties in relation to occupational radiation protection. (A self-employed person is regarded as having the duties of both an employer and a worker.)

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