

IAEA SAFETY STANDARDS SERIES

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

SAFETY GUIDE

No. NS-G-2.7



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

IAEA NS-G-2.7 2002

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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.

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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.

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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;

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