

IAEA Safety Standards

for protecting people and the environment

Protection Against Internal and External Hazards in the Operation of Nuclear Power Plants

Specific Safety Guide

No. SSG-77



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

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

<https://www.iaea.org/resources/safety-standards>

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

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

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PROTECTION AGAINST
INTERNAL AND EXTERNAL
HAZARDS 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".

IAEA SAFETY STANDARDS SERIES No. SSG-77

PROTECTION AGAINST INTERNAL AND EXTERNAL HAZARDS IN THE OPERATION OF NUCLEAR POWER PLANTS

SPECIFIC SAFETY GUIDE

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2022

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Marketing and Sales Unit, Publishing Section
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PO Box 100
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FOREWORD

by Rafael Mariano Grossi
Director General

The IAEA's Statute authorizes it to "establish...standards of safety for protection of health and minimization of danger to life and property". These are standards that the IAEA must apply to its own operations, and that States can apply through their national regulations.

The IAEA started its safety standards programme in 1958 and there have been many developments since. As Director General, I am committed to ensuring that the IAEA maintains and improves upon this integrated, comprehensive and consistent set of up to date, user friendly and fit for purpose safety standards of high quality. Their proper application in the use of nuclear science and technology should offer a high level of protection for people and the environment across the world and provide the confidence necessary to allow for the ongoing use of nuclear technology for the benefit of all.

Safety is a national responsibility underpinned by a number of international conventions. The IAEA safety standards form a basis for these legal instruments and serve as a global reference to help parties meet their obligations. While safety standards are not legally binding on Member States, they are widely applied. They have become an indispensable reference point and a common denominator for the vast majority of Member States that have adopted these standards for use in national regulations to enhance safety in nuclear power generation, research reactors and fuel cycle facilities as well as in nuclear applications in medicine, industry, agriculture and research.

The IAEA safety standards are based on the practical experience of its Member States and produced through international consensus. The involvement of the members of the Safety Standards Committees, the Nuclear Security Guidance Committee and the Commission on Safety Standards is particularly important, and I am grateful to all those who contribute their knowledge and expertise to this endeavour.

The IAEA also uses these safety standards when it assists Member States through its review missions and advisory services. This helps Member States in the application of the standards and enables valuable experience and insight to be shared. Feedback from these missions and services, and lessons identified from events and experience in the use and application of the safety standards, are taken into account during their periodic revision.

I believe the IAEA safety standards and their application make an invaluable contribution to ensuring a high level of safety in the use of nuclear technology. I encourage all Member States to promote and apply these standards, and to work with the IAEA to uphold their quality now and in the future.

THE IAEA SAFETY STANDARDS

BACKGROUND

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

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

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

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

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

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

THE IAEA SAFETY STANDARDS

The status of the IAEA safety standards derives from the IAEA's Statute, which authorizes the IAEA to establish or adopt, in consultation and, where appropriate, in collaboration with the competent organs of the United Nations and with the specialized agencies concerned, standards of safety for protection of health and minimization of danger to life and property, and to provide for their application.

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

Safety measures and security measures¹ have in common the aim of protecting human life and health and the environment. Safety measures and security measures must be designed and implemented in an integrated manner so that security measures do not compromise safety and safety measures do not compromise security.

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

Safety Fundamentals

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

Safety Requirements

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

Safety Guides

Safety Guides provide recommendations and guidance on how to comply with the safety requirements, indicating an international consensus that it

¹ See also publications issued in the IAEA Nuclear Security Series.

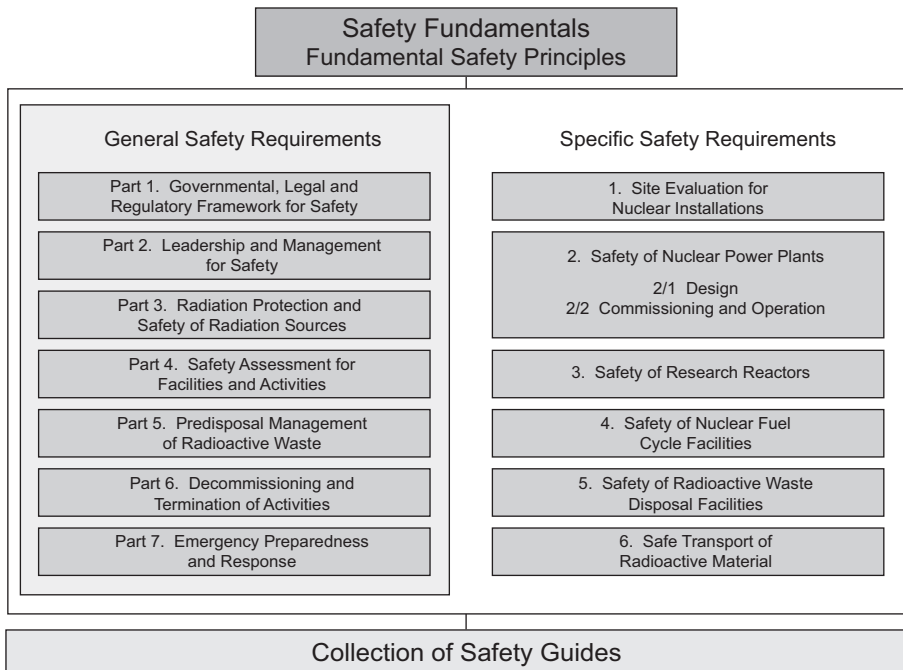


FIG. 1. The long term structure of the IAEA Safety Standards Series.

is necessary to take the measures recommended (or equivalent alternative measures). The Safety Guides present international good practices, and increasingly they reflect best practices, to help users striving to achieve high levels of safety. The recommendations provided in Safety Guides are expressed as ‘should’ statements.

APPLICATION OF THE IAEA SAFETY STANDARDS

The principal users of safety standards in IAEA Member States are regulatory bodies and other relevant national authorities. The IAEA safety standards are also used by co-sponsoring organizations and by many organizations that design, construct and operate nuclear facilities, as well as organizations involved in the use of radiation and radioactive sources.

The IAEA safety standards are applicable, as relevant, throughout the entire lifetime of all facilities and activities — existing and new — utilized for peaceful purposes and to protective actions to reduce existing radiation risks. They can be

used by States as a reference for their national regulations in respect of facilities and activities.

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

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

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

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

DEVELOPMENT PROCESS FOR THE IAEA SAFETY STANDARDS

The preparation and review of the safety standards involves the IAEA Secretariat and five Safety Standards Committees, for emergency preparedness and response (EPReSC) (as of 2016), nuclear safety (NUSSC), radiation safety (RASSC), the safety of radioactive waste (WASSC) and the safe transport of radioactive material (TRANSSC), and a Commission on Safety Standards (CSS) which oversees the IAEA safety standards programme (see Fig. 2).

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

A management system has been established for the processes of planning, developing, reviewing, revising and establishing the IAEA safety standards.

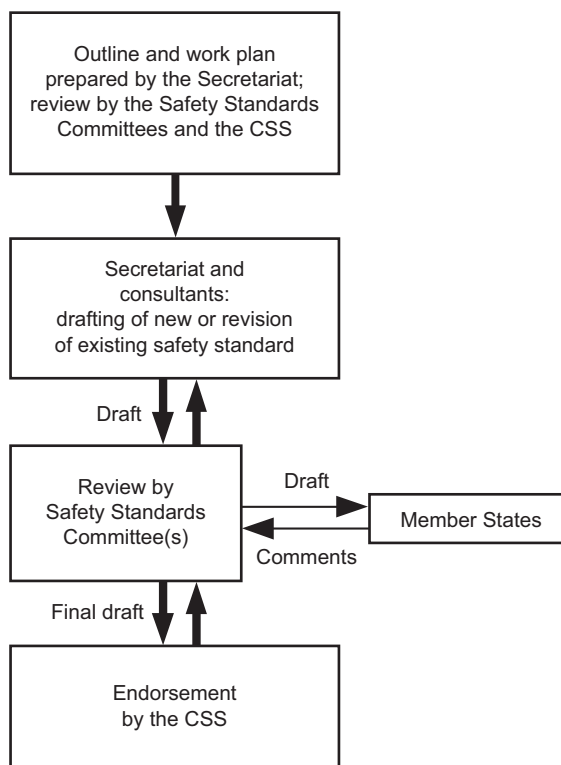


FIG. 2. The process for developing a new safety standard or revising an existing standard.

It articulates the mandate of the IAEA, the vision for the future application of the safety standards, policies and strategies, and corresponding functions and responsibilities.

INTERACTION WITH OTHER INTERNATIONAL ORGANIZATIONS

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

INTERPRETATION OF THE TEXT

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

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

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

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

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1. INTRODUCTION

BACKGROUND

1.1. Requirements for the operation of nuclear power plants are established in IAEA Safety Standards Series No. SSR-2/2 (Rev. 1), Safety of Nuclear Power Plants: Commissioning and Operation [1], while requirements for the design of nuclear power plants are established in IAEA Safety Standards Series No. SSR-2/1 (Rev. 1), Safety of Nuclear Power Plants: Design [2].

1.2. This Safety Guide provides specific recommendations on protection against internal and external hazards in the operation of nuclear power plants. This Safety Guide provides new or updated recommendations derived from enhanced understanding of operational aspects of hazards and combinations of hazards.

1.3. This Safety Guide incorporates the following:

- (a) Progress in regulatory practice in Member States, feedback from safety review missions and the results of recent research on the effects of external events;
- (b) Progress in the operation of nuclear power plants in Member States, considering lessons identified from external events;
- (c) Operating experience gained from incidents and accidents;
- (d) Insights on plant and site specific features relating to internal and external hazards, as well as improvements in the protection measures against such hazards identified in various hazard analyses and probabilistic safety assessments.

1.4. The terms used in this Safety Guide are to be understood as defined and explained in the IAEA Safety Glossary [3].

1.5. Other Safety Guides provide recommendations on protection against internal and external hazards in the design of nuclear power plants and are complementary to this Safety Guide. These Safety Guides include IAEA Safety Standards Series Nos SSG-64, Protection Against Internal Hazards in the Design of Nuclear Power Plants [4]; SSG-67, Seismic Design for Nuclear Installations [5]; and SSG-68, Design of Nuclear Installations Against External Events Excluding Earthquakes [6].

1.6. Operating experience gained from incidents and accidents in nuclear power plants around the world demonstrates that fire continues to be an important risk contributor in many Member States. However, a number of other internal and external hazards also have to be taken into account in the design and operation of nuclear power plants. This Safety Guide supersedes and expands the scope of IAEA Safety Standards Series No. NS-G-2.1, Fire Safety in the Operation of Nuclear Power Plants¹, to include recommendations on these other hazards.

OBJECTIVE

1.7. The objective of this Safety Guide is to provide recommendations on the operation of nuclear power plants in relation to preparation for, prevention of, protection against, mitigation of, and coping with internal and external hazards, including the impacts of those hazards, to meet the requirements established in SSR-2/2 (Rev. 1) [1].

1.8. The recommendations in this Safety Guide are aimed primarily at operating organizations of nuclear power plants and at regulatory bodies. The recommendations may also be of interest to other organizations involved in the design, construction, commissioning, operation and decommissioning of nuclear power plants, including technical support organizations, vendor companies (e.g. designers, engineering contractors, manufacturers), research establishments and universities providing services in support of a nuclear power plant, and organizations involved in mitigating such hazards.

SCOPE

1.9. This Safety Guide applies to water cooled nuclear power plants designed and operated in accordance with the requirements established in SSR-2/1 (Rev. 1) [2] and SSR-2/2 (Rev. 1) [1] and with the recommendations provided in SSG-64 [4], SSG-67 [5] and SSG-68 [6]. For reactors cooled by other media, some of the recommendations in this Safety Guide might not be fully applicable, as application of these recommendations depends on the particular reactor technology and the risks associated with internal and external hazards.

¹ INTERNATIONAL ATOMIC ENERGY AGENCY, Fire Safety in the Operation of Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-2.1, IAEA, Vienna (2000).

1.10. This Safety Guide provides detailed recommendations for the internal fire hazard, which is an important risk contributor for most nuclear power plants. As detailed application of recommendations for other hazards would be site specific, this Safety Guide also provides high level recommendations applicable to a broad range of internal and external hazards.

1.11. The recommendations provided in this Safety Guide are targeted at new and existing nuclear power plants. For water cooled nuclear power plants designed or operated in accordance with earlier standards, it is expected that in their safety assessments a comparison will be made with the current standards to determine whether the safe operation of the plant could be further enhanced by means of reasonably practicable safety improvements (see para. 1.3 of SSR-2/1 (Rev. 1) [2]).

1.12. This Safety Guide does not specifically address safety related risks associated with non-radiation-related hazards to personnel or conventional industrial safety, except where such risks could affect the safety of the nuclear power plant.

1.13. This Safety Guide does not address societal hazards or pathological hazards (e.g. pandemics) that do not directly impact the safety of the nuclear power plant.²

1.14. This Safety Guide does not address postulated internal and external initiating events induced by deliberate human acts of malicious intent, either by on-site personnel or by external adversaries. Guidance on this issue is provided in IAEA Nuclear Security Series No. 13, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5) [8]; No. 35-G, Security During the Lifetime of a Nuclear Facility [9]; and No. 4, Engineering Safety Aspects of the Protection of Nuclear Power Plants against Sabotage [10].

1.15. Paragraph 5.1 of SSR-2/2 (Rev. 1) [1] states that “Safety and security measures shall be designed and implemented in such a manner that they do not compromise each other.” This Safety Guide addresses the interfaces between safety and nuclear security as they relate to the protection of nuclear power plants against internal and external hazards.

² Recommendations to ensure the safety of personnel and the safe operation of nuclear power plants during situations in which a large number of personnel might be unavailable, such as during an epidemic or a pandemic, are provided in IAEA Safety Standards Series No. SSG-72, The Operating Organization for Nuclear Power Plants [7].

STRUCTURE

1.16. Section 2 provides general considerations for the management of internal and external hazards in nuclear power plants. Section 3 focuses on the management system for hazard management. Sections 4 and 5 provide recommendations for ensuring safety against internal hazards and external hazards, respectively. Section 6 provides recommendations on hazard management for combinations of internal and external hazards. Section 7 provides recommendations on updating hazard management. Section 8 provides recommendations on control of materials and housekeeping in hazard management. Section 9 provides recommendations on maintenance, testing, surveillance and inspection of hazard prevention, protection and mitigation measures. Section 10 provides recommendations on training of personnel on hazard management. Appendices I and II provide detailed information on the technical aspects to be considered in protecting against internal hazards and external hazards, respectively.

2. GENERAL CONSIDERATIONS FOR THE MANAGEMENT OF INTERNAL AND EXTERNAL HAZARDS IN NUCLEAR POWER PLANTS

2.1. Internal hazards are those hazards to the safety of the nuclear power plant that originate from within the site boundary and are associated with failures of facilities and activities that are under the control of the operating organization. External hazards are those hazards that originate from outside the site boundary and outside the activities that are under the control of the operating organization, over which the operating organization has very little or no control, but that could have an effect on the safety of the facility or activity. In this Safety Guide, the term ‘hazard’ refers to both internal and external hazards, and to the combination of those hazards, except where specifically noted. Examples of internal hazards and external hazards are provided in paras 5.16 and 5.17 of SSR-2/1 (Rev. 1) [2], and combinations of hazards are discussed in appendix I to SSG-64 [4].

2.2. The term ‘hazard management’ is used to refer to a set of operational processes and measures for hazard prevention, protection and mitigation as well as to strategies for coping with the impact of hazards to ensure the safe operation of nuclear power plants. Hazard prevention, protection and mitigation features in a nuclear power plant are typically safety systems and safety features, but

they might also include systems and features that were not originally installed or designed as safety systems or safety features. Hazard management also includes hazard preparedness, response and recovery actions.

2.3. The requirements relevant to hazard management in the operation of nuclear power plants are established in SSR-2/2 (Rev. 1) [1].

2.4. Requirement 2 of SSR-2/2 (Rev. 1) [1] states that **“The operating organization shall establish, implement, assess and continually improve an integrated management system.”** The integrated management system should incorporate hazard management. Hazard management should aim at preventing, mitigating and coping with hazards and reducing the potential for common cause failure. Considerations for the integration of hazard management within the plant’s management system are presented in Section 3.

2.5. Requirement 11 of SSR-2/2 (Rev. 1) [1] states that **“The operating organization shall establish and implement a programme to manage modifications.”** The operating organization should maintain and keep up to date, as necessary, all features for hazard prevention, protection and mitigation as part of the programme for managing modifications. Recommendations for hazard management and its review in relation to modifications are provided in Sections 3 and 7. Operational provisions for hazard management should be consistent with the recommendations in IAEA Safety Standards Series No. SSG-71, Modifications to Nuclear Power Plants [11]³.

2.6. Requirement 12 of SSR-2/2 (Rev. 1) [1] states:

“Systematic safety assessments of the plant, in accordance with the regulatory requirements, shall be performed by the operating organization throughout the plant’s operating lifetime, with due account taken of operating experience and significant new safety related information from all relevant sources.”

Recommendations for the review and update of the hazard analysis and the development of hazard management through the periodic safety review are provided in Section 7. Operational provisions for hazard management should be

³ SSG-71 [11] provides specific recommendations for the programme for plant modifications, including processes relevant to hazard management measures, such as specific safety consideration for industrial hazards and temporary emergency procedures during modifications.

consistent with the recommendations provided in IAEA Safety Standards Series No. SSG-25, Periodic Safety Review for Nuclear Power Plants [12].

2.7. Requirement 18 of SSR-2/2 (Rev. 1) [1] states that **“The operating organization shall prepare an emergency plan for preparedness for, and response to, a nuclear or radiological emergency.”** Requirement 19 of SSR-2/2 (Rev. 1) [1] states that **“The operating organization shall establish, and shall periodically review and as necessary revise, an accident management programme.”**

2.8. Hazard management and decision making in hazard management should be harmonized with the plant’s arrangements for emergency preparedness and response and with the accident management programme to ensure that the plant can cope with events arising from internal or external hazards and for mitigation of the consequences of these events. Requirements for emergency preparedness and response are established in IAEA Safety Standards Series No. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency [13]; recommendations on preparedness for a nuclear or radiological emergency are provided in IAEA Safety Standards Series No. GS-G-2.1, Arrangements for Preparedness for a Nuclear or Radiological Emergency [14]; and recommendations on occupational radiation protection in a nuclear or radiological emergency are provided in IAEA Safety Standards Series No. GSG-7, Occupational Radiation Protection [15]. Operational provisions for hazard management should be consistent with the recommendations provided in IAEA Safety Standards Series No. SSG-54, Accident Management Programmes for Nuclear Power Plants [16]. Hazard prevention, protection and mitigation features include fixed or non-permanent equipment used to restore the safety functions and to reach and maintain a safe state during an accident caused by external hazards [16].

2.9. Requirement 22 of SSR-2/2 (Rev. 1) [1] states that **“The operating organization shall make arrangements for ensuring fire safety.”** Paragraph 5.21 of SSR-2/2 (Rev. 1) [1] further states:

“The arrangements for ensuring fire safety made by the operating organization shall cover the following: adequate management for fire safety; preventing fires from starting; detecting and extinguishing quickly any fires that do start; preventing the spread of those fires that have not been extinguished; and providing protection from fire for structures, systems and components that are necessary to shut down the plant safely. Such arrangements shall include, but are not limited to:

- (a) Application of the principle of defence in depth;
- (b) Control of combustible materials and ignition sources, in particular during outages;
- (c) Maintenance, testing, surveillance and inspection of fire protection measures;
- (d) Establishment of a manual firefighting capability;
- (e) Assignment of responsibilities and training and exercising of plant personnel;
- (f) Assessment of the impact of plant modifications on fire safety measures.”

The recommendations for hazard management specifically relating to fire safety are provided in Appendix I, paras I.2–I.52. Special attention should be paid to the application of the principle of defence in depth for fire safety (see para. 2.23).

2.10. Requirement 23 of SSR-2/2 (Rev. 1) [1] states:

“The operating organization shall establish and implement a programme to ensure that safety related risks associated with non-radiation-related hazards to personnel involved in activities at the plant are kept as low as reasonably achievable.”

Paragraph 5.26 of SSR-2/2 (Rev. 1) [1] further states [footnote omitted]:

“The non-radiation-related safety programme shall include arrangements for the planning, implementation, monitoring and review of the relevant preventive and protective measures, and it shall be integrated with the nuclear and radiation safety programme.”

The operating organization should consider industrial hazards when implementing hazard management.

2.11. Requirement 26 of SSR-2/2 (Rev. 1) [1] states:

“Operating procedures shall be developed that apply comprehensively (for the reactor and its associated facilities) for normal operation, anticipated operational occurrences and accident conditions, in accordance with the policy of the operating organization and the requirements of the regulatory body.”

The operating procedures for hazard management should be developed in accordance with the requirements established in paras 7.1–7.6 of SSR-2/2 (Rev. 1) [1]. Operational provisions for hazard management should be consistent with the recommendations provided in IAEA Safety Standards Series No. SSG-70, Operational Limits and Conditions and Operating Procedures for Nuclear Power Plants [17].

2.12. Requirement 28 of SSR-2/2 (Rev. 1) [1] states that **“The operating organization shall develop and implement programmes to maintain a high standard of material conditions, housekeeping and cleanliness in all working areas.”** Paragraph 7.10 of SSR-2/2 (Rev. 1) [1] further states:

“Administrative controls shall be established to ensure that operational premises and equipment are maintained, well lit and accessible, and that temporary storage is controlled and limited. Equipment that is degraded (owing to leaks, corrosion spots, loose parts or damaged thermal insulation, for example) shall be identified and reported and deficiencies shall be corrected in a timely manner.”

The operating organization should consider the potential for hazards, hazard progression and hazard consequences when developing and implementing programmes to maintain proper material conditions and housekeeping. The operating organization should maintain proper housekeeping at all times, even if some actions are important only at times when a particular external hazard is forecast. Operational provisions for hazard management should be consistent with the recommendations provided in IAEA Safety Standards Series No. SSG-76, Conduct of Operations at Nuclear Power Plants [18]⁴.

2.13. Requirement 31 of SSR-2/2 (Rev. 1) [1] states that **“The operating organization shall ensure that effective programmes for maintenance, testing, surveillance and inspection are established and implemented.”** The operating organization should identify internal hazards that might arise during maintenance, testing, surveillance and inspection activities. These internal hazards should be taken into account when developing hazard management. Hazard management for both internal and external hazards should be considered when developing

⁴ SSG-76 [18] provides specific recommendations for the management programme for plant operations, including processes relevant to hazard management such as operational limits and conditions and/or procedures for hazards, communication between plant personnel during hazards, shift rounds to monitor indication of hazards, deviations in fire protection, condition of protection features for flooding, seismic constraints, unsecured components and housekeeping.

programmes for maintenance, testing, surveillance and inspection. Operational provisions for hazard management should be consistent with the recommendations provided in IAEA Safety Standards Series No. SSG-74, Maintenance, Testing, Surveillance and Inspection in Nuclear Power Plants [19]⁵.

2.14. Requirement 32 of SSR-2/2 (Rev. 1) [1] states: **“The operating organization shall establish and implement arrangements to ensure the effective performance, planning and control of work activities during outages.”** The operating organization should identify hazards that might arise during outages, including during low power and shutdown modes. Hazard management should take into account the dynamic changes in plant conditions — including changes in structures, systems and components — and factors such as the availability of safety systems or safety features and increased resource needs (e.g. additional workers, combustible materials, scaffolding or vehicles) during outages and shutdown. In this regard, hazard management should also take into account the long term shutdown needed for refurbishment to enable long term operation.

2.15. Requirement 33 of SSR-2/2 (Rev. 1) [1] states:

“The operating organization shall prepare a decommissioning plan and shall maintain it throughout the lifetime of the plant, unless otherwise approved by the regulatory body, to demonstrate that decommissioning can be accomplished safely and in such a way as to meet the specified end state.”

The operating organization should ensure that hazard management is included in the decommissioning plan, and any changes in the assessed hazards during decommissioning should be taken into account.

2.16. Hazard management should consider the hazards occurring at each reactor unit at a multiple unit site. It should also include consideration of hazards at collocated or nearby nuclear power plants, even if operated by different operating organizations. Hazard management should also address hazards relating to the use of shared spent fuel pools.

⁵ SSG-74 [19] provides specific recommendations for the programme for maintenance, testing, surveillance and inspections, including processes relevant to hazard management such as the following: work control and administrative procedures for fire hazard control; surveillance programmes for equipment for mitigation of and coping with hazards; and management for limiting the risk of fire, flooding, earthquake, missiles and release of hazardous substances.

2.17. Hazards might lead to a release of radioactive material and associated hazardous material by inducing internal or external events that might cause equipment failures, degrade the performance of barriers or degrade means for preventing harmful effects.

2.18. While it might not be practical or possible to prevent a hazard or its impacts from triggering an anticipated operational occurrence, hazard management should ensure that, to the extent practicable, a hazard does not trigger a more severe plant state, leading to accident conditions. For example, hazard management could help prevent a single fire event from causing multiple safety system failures.

2.19. Hazards should be considered in the planning and conduct of inspections. Inspections should be implemented for equipment and features used for hazard detection, for hazard prevention or mitigation, and for coping with hazards or hazard impacts.

2.20. Operational provisions for hazard management should be also consistent with the recommendations provided in SSG-72 [7] and IAEA Safety Standards Series No. SSG-75, Recruitment, Qualification and Training of Personnel for Nuclear Power Plants [20].

APPLICATION OF DEFENCE IN DEPTH FOR HAZARD MANAGEMENT

2.21. In accordance with the objectives of defence in depth, the operating organization should establish procedures to operate the features for hazard prevention, protection and mitigation for all hazards and should implement strategies for coping with the impact of hazards to ensure that the fundamental safety functions are maintained for all plant states.

2.22. To protect the plant from hazards, the operating organization should follow the approach to defence in depth applicable during operation by a combination of maintaining engineered safety features, ensuring automatic actuation of safety systems and proper operator actions, and maintaining systems, structures and components, as presented in Requirement 7 of SSR-2/1 (Rev. 1) [2], and by implementing operating procedures, as presented in Requirement 26 of SSR-2/2 (Rev. 1) [1]. The operating procedures provide additional support to the engineered safety features in the implementation of defence in depth against hazards (by monitoring for, warning of and alerting plant personnel to unanticipated failures) and in post-event management and assessment.

2.23. In accordance with Requirement 22 of SSR-2/2 (Rev. 1) [1] and Requirement 7 of SSR-2/1 (Rev. 1) [2], the operating organization should verify that the concept of defence in depth for internal fire hazards is applied in accordance with the corresponding operational limits and conditions (see Appendix I, paras I.2–I.4).

3. APPLICATION OF THE MANAGEMENT SYSTEM TO HAZARD MANAGEMENT

MANAGEMENT RESPONSIBILITY FOR HAZARD MANAGEMENT

3.1. The operating organization should establish a set of hazard management measures to ensure that the plant can be protected against hazards by suitable design and operational activities — including prevention and mitigation of the impact of, and coping with the consequences of, hazards or credible combinations of hazards, according to SSG-64 [4] — in an integrated management system.

3.2. The operating organization should be able to maintain the fundamental safety functions of the nuclear power plant during and after the impact of individual hazards or a credible combination of hazards. The operating organization should use all available resources to cope with hazard impacts and reduce the likelihood that these impacts would propagate, become more severe or jeopardize the fundamental safety functions.

3.3. In accordance with IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [21], the roles and responsibilities of personnel involved in the establishment, implementation and administration of hazard management are required to be defined, documented and kept up to date in the management system. Arrangements for delegation of authority for these responsibilities should also be documented, implemented and kept up to date. Further recommendations on the management system for nuclear installations are provided in IAEA Safety Standards Series No. GS-G-3.5, The Management System for Nuclear Installations [22].

3.4. The operating organization should identify the organizational structures, processes, specific responsibilities and levels of authority of personnel, as well as the interfaces between personnel involved in hazard management within the organization and with external organizations, if necessary. Identification of these

external organizations should take into account specific site challenges, plant design aspects, and regional and national governmental structure.

3.5. The plant management is responsible for deploying protective measures in a timely manner when hazardous conditions are forecast. Before any event occurs, the operating organization should identify and establish the necessary staffing levels, the capabilities of the personnel, and the personnel roles and responsibilities needed to mitigate and cope with hazards.

3.6. The operating organization should establish and document plans and protocols for hazard management and should ensure that plant personnel are trained and qualified in these plans and protocols. The operating organization should involve a combination of personnel from various site sections or departments — including engineering, operations, maintenance, technical support and emergency response — in the development and application of these plans and protocols and should consider insights from external organizations, such as vendors, as appropriate. The operating organization should also ensure that an adequate number of competent and qualified staff is available at all times to operate the plant safely in operational states and accident conditions in the event of hazards and induced effects [18].

3.7. The operating organization should organize a response team with the appropriate qualifications, skills and training in the use of equipment for hazard mitigation and coping with consequences (see Section 10).

PROCESS IMPLEMENTATION AND RESOURCE MANAGEMENT FOR HAZARD MANAGEMENT

3.8. Hazard management is required to be integrated with the nuclear and radiation safety programme of the nuclear power plant (see Requirements 8 and 17–24 of SSR-2/2 (Rev. 1) [1]).

3.9. The set of hazard management measures should be structured, documented and associated with the plant's management system and based on the safety assessment, in accordance with the requirements established in SSR-2/2 (Rev. 1) [1]. Further recommendations on the management of plant operations are provided in SSG-72 [7], and recommendations on the development of operational procedures for hazard management measures are provided in SSG-76 [18].

3.10. The incorporation of measures for protection against hazards into the plant's management system should be based on a graded approach in accordance with the hazards and the magnitude of their potential impact [21]. Factors to be taken into consideration also include site specific hazards and the magnitude of their potential impact, the extent and difficulty of the efforts needed to implement a protection activity against those hazards, the number of related processes, the overlap of the processes, and the optimization of resources.

3.11. Hazard management and decision making for hazard management should be harmonized with the guidance and actions included in the plant's arrangements for emergency preparedness and response and the accident management programme. Requirements on preparedness for a nuclear or radiological emergency are established in GSR Part 7 [13], and recommendations are provided in GS-G-2.1 [14]. Recommendations on accident management are provided in SSG-54 [16].

3.12. Hazard management should consider and include processes, procedures and measures for the following:

- (a) Prevention of hazards;
- (b) Detection of hazards;
- (c) Protection against and mitigation of the impact of hazards or credible combinations of hazards;
- (d) Strategies for coping with the impact of hazards, including measures to be implemented to deal with an adverse situation for an indefinite period of time.

3.13. Hazard management should be maintained so that it remains applicable and relevant to the plant throughout the plant's entire lifetime. Hazard management should be reviewed periodically and updated as necessary to consider any changes in the plant (including plant modifications), changes in the site characteristics, results of research and development, new scientific knowledge, and lessons and best practices from operating experience at the plant or at other plants. The results of this periodic review should be used to identify and implement in a timely manner any practicable design modifications and changes to hazard management, including organizational arrangements, strategies and measures.

3.14. The operating procedures for hazard management should set out the roles, responsibilities and tasks of plant personnel in relation to the roles of any external organizations (e.g. law enforcement organizations, off-site firefighters).

3.15. Strategies for coping with hazard impacts should be developed as a part of hazard management. These strategies should take into account the infrastructure of the region around the site, such as roads, railways, electrical grid interfaces, communications and sources of water, as well as proximity to waterways, regional population centres and local industries. Particular consideration should be given to infrastructure that might present challenges to the site or that might itself be affected by the hazard if it is being relied on as part of the strategies for coping with the impact of hazards.

3.16. Hazard management should identify relevant external resources and organizations — such as local government, emergency services and response organizations — and the type and amount of support that these regional external organizations can provide, as well as the points of contact and methods of communication with these organizations.

3.17. Early warning protocols should be established, and cooperation with external organizations should be planned and trained in drills (see Section 10). Communication with external organizations should be tested, and communication protocols should be updated periodically by the operating organization.

3.18. The operating organization should establish separate (or integrated, where appropriate) procedures for different types of hazard. These procedures should provide clear instructions to the personnel on actions to be implemented if precursors or indications of hazards are observed or if hazard induced precursors to initiating events occur.

3.19. The emergency arrangements of the operating organization and of external organizations should ensure that special consideration is given to cases where there is a risk of radioactive releases as a consequence of an event caused by a hazard. The aim should be to meet the goals of emergency response, as stated in GSR Part 7 [13].

3.20. Hazard management should be performance based; that is, the approach should define a desired outcome and clear, objective and measurable criteria to determine whether that outcome has been reached.

3.21. Hazard management should include provisions to ensure the protection of those personnel responsible for implementing the measures for hazard protection and mitigation and the strategies for coping with hazard impact. These provisions should cover the radiation protection of personnel of both the operating organization and external organizations who would be implementing actions at

the plant (e.g. off-site firefighters). Recommendations on protection of workers are provided in GSG-7 [15].

DECISION MAKING FOR HAZARD MANAGEMENT

3.22. In accordance with the requirements established in GSR Part 2 [21], the operating organization is required to develop and maintain an understanding of the radiation risks and hazards associated with the nuclear power plant.

3.23. The plant management should have an understanding of how safety systems and safety features, as well as hazard prevention, protection and mitigation features, could be adversely affected by hazards, taking into consideration the safety assessment and a graded approach [23]. This includes an understanding of hazard management measures to increase the plant's resilience to hazards.

3.24. The plant management should have an understanding that certain nuclear security features might also be adversely affected by the impact of hazards or the activation of hazard mitigation measures.

3.25. To meet the requirements established in GSR Part 2 [21], the operating organization should ensure that the plant management remains capable of activating established programmes, processes and procedures to protect the plant against hazards and is prepared to implement hazard mitigation measures and strategies for coping with hazard impact.⁶ The following aspects should be taken into consideration, as appropriate:

- (a) Cooperation with regional and national external organizations. The operating organization should establish communication arrangements with appropriate external organizations as early as possible to allow timely predictions of hazards, which could be used as input for the decision making process, and to ensure that hazard management measures such as firefighting or transport of equipment (e.g. drainage pumps), which might be stored off-site, can be activated. Sections 4 and 5 of this Safety Guide provide further examples of such cooperation with external organizations.

⁶ To do this, the operating organization can create an overview document of the processes contained in each management programme and add appropriate information to these programmes that will allow for efficient decision making. An example of such an overview document, or checklist, for a tropical storm is presented in Appendix II, para. II.32.

- (b) Nuclear security aspects. Hazard management should be developed in consultation with experts in nuclear security and should include procedures to inform nuclear security personnel of any modifications to the nuclear security features and of the occurrence of any hazard to ensure that the necessary actions are implemented. Further guidance on nuclear security is provided in Refs [8–10, 24].
- (c) Multiple unit plant sites. For multiple reactor units collocated on the same site or at adjacent sites, whether they are operated by the same or by different operating organizations, the operating organization should consider how the site and the organizational configuration affect the hazard mitigation measures and strategies for coping with hazard impact, especially for predictable hazards. The operating organizations should ensure appropriate cooperation with other operating organizations at the same site or at adjacent sites.

3.26. When a hazardous event has occurred or hazardous conditions have been forecast, a hazard response procedure should be initiated by the operating organization to ensure the following:

- (a) Timely actuation of the appropriate level of response;
- (b) Performance of time-sensitive actions and confirmation of these actions to manage the risk imposed by the hazard;
- (c) Identification of any support needed (e.g. support from external organizations, emergency support equipment, specialized personnel);
- (d) Maintaining of the fundamental safety functions required for the corresponding plant conditions;
- (e) Identification of alternative actions if a specific action cannot be performed.

4. ENSURING SAFETY AGAINST INTERNAL HAZARDS IN THE OPERATION OF NUCLEAR POWER PLANTS

4.1. Internal hazards are required to be taken into account in the design (SSR-2/1 (Rev. 1) [2]) and the operation (SSR-2/2 (Rev. 1) [1]) of a nuclear power plant.

4.2. In accordance with Requirement 10 of IAEA Safety Standards Series No. GSR Part 4 (Rev. 1), Safety Assessment for Facilities and Activities [23], an initial hazard analysis is required to be part of the design stage. The frequency of