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

IAEA
International Atomic Energy Agency

IAEA SAFETY STANDARDS AND RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

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

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

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

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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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The IAEA provides for the application of the standards and, under the terms of Articles III and VIII.C of its Statute, makes available and fosters the exchange of information relating to peaceful nuclear activities and serves as an intermediary among its Member States for this purpose.

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Other safety related IAEA publications are issued as **Emergency Preparedness and Response** publications, **Radiological Assessment Reports**, the International Nuclear Safety Group's **INSAG Reports**, **Technical Reports** and **TECDOCs**. The IAEA also issues reports on radiological accidents, training manuals and practical manuals, and other special safety related publications.

Security related publications are issued in the **IAEA Nuclear Security Series**.

The **IAEA Nuclear Energy Series** comprises informational publications to encourage and assist research on, and the development and practical application of, nuclear energy for peaceful purposes. It includes reports and guides on the status of and advances in technology, and on experience, good practices and practical examples in the areas of nuclear power, the nuclear fuel cycle, radioactive waste management and decommissioning.

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

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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 measures[1] 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

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

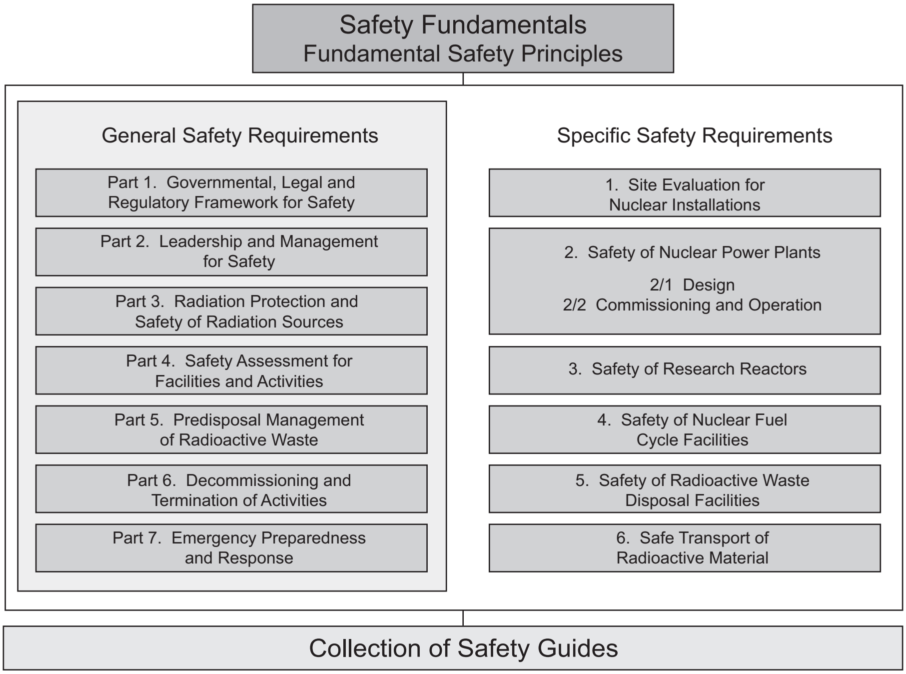

FIG. 1. The long term structure of the IAEA Safety Standards Series.

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.

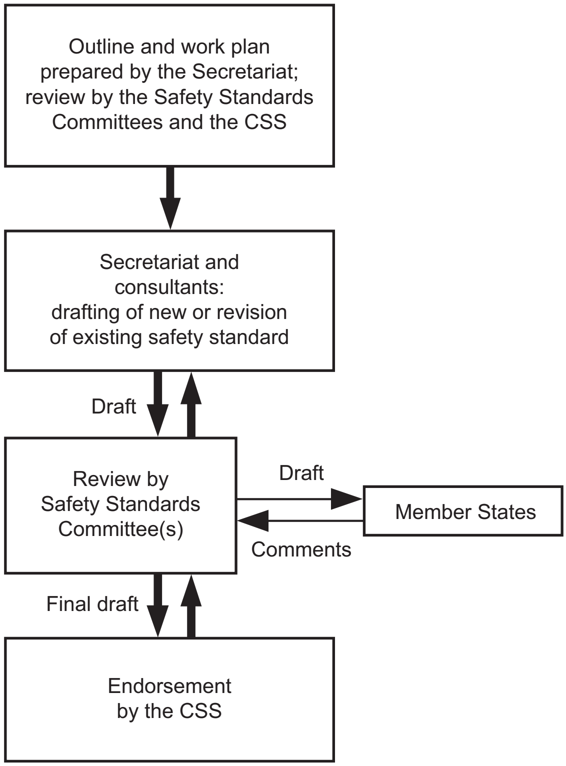

FIG. 2. The process for developing a new safety standard or revising an existing standard.

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.

CONTENTS

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 Plants[1], 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.

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[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.

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[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.

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[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.2–1.4).

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.

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[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 occurrence of internal hazards can be reduced and their effect can be mitigated to a large extent by the design and construction of engineered safety features. This initial hazard analysis should be supplemented to take into account the operational procedures for preventing, protecting against, mitigating and coping with internal hazards. Site specific aspects (especially for multiple unit sites or sites on which multiple radiation sources are located) are also required to be considered in the plant design and safety assessment against internal hazards (see Requirement 17 of SSR-2/1 (Rev. 1) [2], and IAEA Safety Standards Series No. SSG-3, Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants [25]) and in the operation of the plant.

4.3. The hazard analysis and the operating procedures for hazard management for internal hazards should be updated regularly over the lifetime of the plant to reflect lessons from operating experience (see Section 7).

4.4. The hazard analysis should consider the impact of all credible internal hazards on structures, systems and components. This hazard analysis will be a part of hazard management (see Section 3). Recommendations on protection against internal hazards in the design and safety assessment of nuclear power plants are provided in SSG-64 [4] and SSG-3 [25].

4.5. Hazard management should include strategies for the deployment of personnel and equipment as well as the procedural implementation of those strategies. Where additional personnel or equipment need to be deployed for hazard mitigation, hazard management should specify the means of communication with external organizations and should include training and practice drills for personnel (see Section 10).

4.6. Enhanced administrative and procedural controls of materials and housekeeping should be put in place (see Section 8) as part of hazard management for periods of increased risk (e.g. during outages, during the implementation of modifications) to ensure that the hazard prevention, protection and mitigation features are not reduced.

4.7. Hazard management should define the role of personnel in controlling actions to respond to the challenges of hazards. Personnel should be able to implement protection measures, to reduce the extent of the effects of specific hazards by realignment of systems or equipment, or to address impacts from the hazard by initiating on-site actions as part of strategies for coping with the impact of the hazard on the plant.

4.8. Hazard management for internal hazards should include the following elements, which should be adapted to the specific characteristics of each hazard:

(a) Identification of a response level commensurate with the hazard and the potential consequences;
(b) Identification of warning or monitoring systems and equipment appropriate for the hazard;
(c) Identification and assessment of the safety challenges and functional challenges caused by the hazard (e.g. challenges to specific equipment needed for protection from the hazard);
(d) Development and implementation of procedures for maintenance and inspection of equipment needed to cope with and mitigate the impact of the hazard;
(e) Development and implementation of standards and protocols for communication with external organizations;
(f) Training of personnel to ensure the development of necessary skills for implementing hazard prevention, protection and mitigation measures;
(g) Identification of the equipment and tools needed to mitigate the effect of the hazard.

RECOMMENDATIONS FOR SPECIFIC INTERNAL HAZARDS

4.9. Recommendations for design related aspects of internal hazards are provided in SSG-64 [4]. For all credible internal hazards, including combined hazards (see Section 6), the general recommendations provided in paras 4.1–4.8 are applicable.

4.10. Appendix I is not exhaustive but provides detailed recommendations for hazard management of the following commonly considered internal hazards:

(a) Internal fires;
(b) Internal explosions;
(c) Internal missiles;
(d) Pipe breaks (including secondary consequences such as pipe whip, jet effect, flooding and pressure buildup);
(e) Internal flooding;
(f) Heavy load drop;
(g) Electromagnetic interference;
(h) Release of hazardous substances inside the plant.

5. ENSURING SAFETY AGAINST EXTERNAL HAZARDS IN THE OPERATION OF NUCLEAR POWER PLANTS

5.1. Hazard management for protection against external hazards should be based on the identification of site specific external hazards and plant vulnerabilities. Such hazards and vulnerabilities are identified through or in connection with, for example, site evaluation, plant design, periodic safety reviews, evaluation of operating experience, and — if applicable — probabilistic safety assessments for external hazards. Levels of hazard more severe than those considered in the design should also be considered in hazard management as an interface with accident management, in accordance with the evaluation of the impact of these hazards. SSG-67 [5] and SSG-68 [6] provide recommendations on the design aspects relating to external hazards, including hazard analysis. Recommendations on safety assessment for external hazards are provided in SSG-3 [25]. Results of the design and safety assessment for external hazards should be taken into account by the operating organization, and any changes in safety assessment should be reviewed as part of the periodic updating process for hazard management (see Section 7).

5.2. On the basis of the external hazard impacts evaluated in hazard management, measures for protection and mitigation should be identified that can increase the viability of a strategy for coping with the impact of external hazards.

5.3. Before establishing processes and procedures for protection against external hazards, the operating organization should put in place processes and procedures to ensure that meteorological forecasts are monitored and that appropriate actions will be taken in a timely manner when weather related hazardous conditions (e.g. coastal flooding, severe storms, tornadoes) are forecast. For predictable or partially predictable hazards[7], the operating organization should undertake the hazard response procedure set out in para. 3.26 to ensure that the site is prepared in a timely manner. To reflect local conditions, the operating organization should

[7] The basis of a valid forecast or prediction comprises facts collected through formalized methods and forecasting technologies, which are used to create data. The resulting predictions are available from national and regional organizations that specialize in the production and provision of such forecasts. On-site monitoring can support the information. On this basis, decisions can be made with a certain confidence.

record and maintain data on on-site meteorological conditions and water levels to provide enhanced prediction and forecasting at the local level.

5.4. The operating organization should establish protocols for effective notification of external organizations in advance, taking into consideration events at the site or in the external zone (e.g. temporary increases in population and traffic, the dispatch plan of external organizations, third party activities such as rally groups or demonstrations). This notification protocol should provide clear guidance for both the operating organization and external organizations to implement pre- and post-event actions.

5.5. Hazard management should include strategies for the deployment of personnel and equipment as well as the procedural implementation of those strategies.

5.6. Enhanced administrative and procedural controls of materials and housekeeping should be put in place (see Section 8) for periods of increased risk (e.g. during outages, during the implementation of modifications) to ensure that the hazard protection and mitigation measures are not reduced.

5.7. Hazard management for external hazards should include the following elements, which should be adapted to the specific characteristics of each hazard:

(a) Identification of a realistic ability to forecast the hazard and/or a forecast lead time for the hazard (see para. 5.10), and response criteria commensurate with the hazard identified and the potential consequences;
(b) Identification of warning or monitoring systems and equipment appropriate for the hazard;
(c) Identification and assessment of potential challenges to the fundamental safety functions caused by the hazard (e.g. specific items of equipment that might need to be protected against the hazard);
(d) Development and implementation of an operational strategy for responding to events with warning (e.g. procedures to support anticipatory actions), taking into consideration the seasonal patterns of frequency and/or magnitude of the hazard, for certain natural external hazards;
(e) Development and implementation of procedures for maintenance and inspection of equipment needed to cope with and mitigate the hazard, and demonstration of the continued functional capability of structures, systems and components after the hazardous conditions have passed;
(f) Development and implementation of a strategy for responding to events without warning (e.g. debris removal following a seismic event);

(g) Development and implementation of protocols for communication with external organizations;
(h) Training of personnel to ensure development of the necessary skills for implementing hazard mitigation measures.

5.8. The operating organization should establish operating procedures that describe actions before, during and after the event corresponding to each external hazard, including any preparatory actions before the hazard impacts the site. The operating organization should define and take into account all additional hazards that can be generated by an original hazard and should also define credible combinations of hazards according to SSG-64 [4] (see Section 6).

5.9. The operating organization should take actions to mitigate the propagation of hazard effects throughout the entire site before the event (for a forecast event) or during the event for an external hazard that impacts a vulnerable or sensitive part of the site. These actions should include ensuring that site access routes are available and useable or providing alternative means of site access (e.g. by boat or helicopter) if the site access routes are impacted by the hazard. To ensure the availability of site access routes, protocols for effective communication with and notification of external organizations should be established by the operating organization. Adverse working conditions of personnel because of the hazard should be taken into consideration when developing the operating procedures for hazard management. The safety of personnel should be taken into account, particularly during an event.

5.10. The ability to forecast external hazards varies. Some external hazards — such as seismic events, aircraft crashes and industrial accidents — are generally unpredictable, and hazard management should assume that there will be no warning. Other hazards might be able to be forecast, depending on the phenomenon and the forecast lead time. For example, external floods on certain large river systems can be forecast with considerable accuracy days to weeks in advance. Coastal flooding due to tropical and extratropical storms can be forecast hours to days in advance. Conditions favourable for the formation of severe storms and tornadoes can be forecast using the distribution of atmospheric pressure hours in advance, but there might be very little warning about the precise location and intensity of such phenomena. Hazard management should consider the forecast capability for each credible external hazard, and measures should be developed for hazard protection and mitigation and strategies for coping with hazard impact that are consistent with the respective forecast capability. These measures should include actions to secure loose materials or unsecured equipment to minimize the hazard impact (e.g. of high winds or tornadoes) and the removal of items that could prevent proper site drainage (e.g. in the event of heavy rainfall or storm surges). Communication and notification protocols should ensure that personnel are aware of the likelihood of a specific hazard.

5.11. Depending on the ability to forecast the external hazard (including combined hazards) and the communication with external organizations and agencies, plant shutdown or power reduction should be considered as a pre-event action, especially if there is potential for a station blackout or loss of the ultimate heat sink.

5.12. Depending on the expected severity of the external hazard and the available time, the operating organization should consider evacuating all non-essential plant personnel in accordance with established evacuation procedures.

5.13. After the cancellation of a national or regional hazard warning, the operating organization should take any necessary actions to return the plant to normal operation, including, as appropriate, inspection and remedial actions to ensure that sufficient protection is reinstated. This includes returning any personnel temporarily assigned to coping with the hazard to their normal duties in a controlled manner.

RECOMMENDATIONS FOR SPECIFIC EXTERNAL HAZARDS

5.14. For all external hazards, the recommendations provided in paras 5.1–5.13 are applicable. Appendix II is not exhaustive but provides more detailed recommendations for hazard management of the following common external hazards:

(a) Seismic hazards;
(b) External floods (i.e. storm surges and tsunamis);
(c) External floods (i.e. flooding of rivers and streams, and floods due to extreme precipitation events);
(d) Extreme winds;
(e) Other extreme meteorological conditions;
(f) Volcanism;
(g) External fires;
(h) External explosions;
(i) Hazardous substances (e.g. toxic, radioactive, flammable, corrosive or asphyxiant chemicals, and their air and liquid mixtures, including inadvertent releases from nuclear or other installations in the neighbourhood or on the nuclear power plant site);

(j) Aircraft crashes;
(k) Electromagnetic interference, including solar storms;
(l) Biological phenomena;
(m) Hazards from floating objects and hazardous liquid on water intakes and components of the ultimate heat sink.

6. HAZARD MANAGEMENT FOR COMBINATIONS OF HAZARDS

6.1. This Safety Guide provides recommendations on developing a performance based approach to the management of hazard combinations. It does not prescribe steps for each specific combination nor how to determine which combinations of hazards are credible.

6.2. Hazard management should take into consideration the effects of combined hazards, according to SSG-64 [4], and mitigation strategies against these combined hazards. Some examples of consideration in hazard management for combinations of hazards are given in Appendices I and II.

6.3. Any consequential effects from credible hazard combinations of external–external events, external–internal events and internal–internal events, including unrelated combinations, as defined by plant design and applicable regulations, should be considered in hazard management.

6.4. The goal of hazard management should be to ensure that the plant can withstand the impact of any credible combination of hazards and their effects. Hazard management should include information on how combinations of hazards could alter the overall situation of the plant and how this should be handled. Combinations of hazards can alter hazard mitigation measures and strategies for coping with hazard impact, operating procedures, the special hazard mitigation equipment needed, the internal and external organizations that need to be involved, communication protocols, and the restoration of any deteriorated or damaged hazard mitigation features after an event.

6.5. The operating organization should review the applicability of operating procedures and the deployment of the necessary mitigation equipment for each individual hazard, taking into account the potential effects of the credible combinations of hazards applicable at the site. Consideration should be given to ensuring that operating procedures for separate hazards do not contain conflicting instructions that might lead to confusion if the hazards were to occur in combination. For example, hazard mitigation equipment for a certain hazard should not be stored in an area that could be affected by another subsequent hazard, so that equipment can be used in cases where both hazards occur in combination.

6.6. If combined events occur that have not been anticipated in the safety assessment, then the precautionary conservative hazard response procedure should apply (see para. 3.26). For example, for plants that are in operation at the time of occurrence of combined events, shutdown or power reduction should be considered by the operating organization. The personnel should then follow the accident management programme for the site as a whole, in accordance with Requirement 19 of SSR-2/2 (Rev. 1) [1] and the recommendations provided in SSG-54 [16]. For example, anticipation and consideration of a combination of hazards categorized as unrelated (i.e. independent) events [4] might not be appropriate unless the combination of events is shown to have a sufficient probability in the safety assessment [6]. The operating organization should maintain situational awareness when responding to such events that have not been anticipated in the safety assessment and should use judgement to ensure that the fundamental safety functions are maintained. Such situational awareness should also include consideration of the performance of response organizations and the conditions in which they are operating at the time of response.

6.7. The operating organization should be aware of the potential for the mitigation of one hazard to cause the initiation of other hazards (i.e. consequential or correlated hazards).

6.8. Protocols for communication with plant personnel or communication with external organizations should take hazard combinations into account. These communication protocols should be developed considering the effects of combinations of hazards based on specific plant conditions. For example, different external organizations might need to be involved in the response to certain hazards. If there are multiple hazards, more organizations, with different roles and responsibilities, might be involved in the response. Consideration should be given to ensuring that these roles and responsibilities do not overlap or conflict with one another.

6.9. The performance based approach should be developed using a systematic process to identify and categorize hazard combinations. The hazard mitigation measures and strategies for coping with hazard impact should then be screened in accordance with the significance of each hazard combination's effects on the plant and the frequency of occurrence. SSG-64 [4] provides three categories of hazard combination: consequent (subsequent) events, correlated events and unrelated (independent) events. For example, the hazard mitigation measures and strategies for coping with hazards that arise from consequent events should receive more attention than hazards that arise from independent events.

6.10. For the defined hazard combinations, the operating organization should consider the duration of the consequential effects of each hazard, rather than the duration of the hazard itself. For example, a seismic event might last tens of seconds, but the overall measures for hazard management implemented by personnel for the response could last several days or weeks. If a severe rainfall event occurs during the repair period after the seismic event, the measures for mitigation of the rainfall event could be different than they would be if the plant were operating in normal conditions. The response by plant personnel for these cases should be based not only on the response criteria for both individual hazards but also on specific management measures that relate to the combination of these hazards.

7. PERIODIC UPDATING OF HAZARD MANAGEMENT

7.1. Understanding of the potential effects of hazards on the plant and of the importance of maintaining the fundamental safety functions should be continuously sustained. Continuous or frequent periodic monitoring of external hazards should be considered, and hazard management should be periodically updated, throughout the lifetime of the plant.

7.2. The method for hazard analysis and hazard management should be consistent with the plant design bases and the design assumptions. Hazard management should be reviewed and updated in the following cases:

(a) If additional hazards or hazard combinations are identified, according to SSG-64 [4];
(b) If there is a reassessment of the severity of an initially considered hazard or the ability to withstand this hazard in the specific stage of the plant's lifetime;
(c) As part of the ageing management and programme for long term operation, as described in IAEA Safety Standards Series No. SSG-48, Ageing

Management and Development of a Programme for Long Term Operation of Nuclear Power Plants [26];

(d) As part of a relicensing application;

(e) As part of a periodic safety review, as described in SSG-25 [12];

(f) If new or updated information for a site specific event shows that the current design basis and design assumptions for hazard mitigation measures or strategies might be inadequate, including information on cliff edge effects or challenges to multiple layers of defence in depth that were not previously identified or addressed.

Updating of hazard management should include harmonization with other plant programmes, such as monitoring programmes or emergency arrangements.

7.3. Hazard management should be considered an important contributor to the overall safety assessment for the plant and should be used as an input to operational decision making.

7.4. The operating organization should also take into consideration operating experience from events that have already occurred at the plant or elsewhere. Further recommendations on implementing an operating experience programme to improve plant equipment, procedures and training are provided in IAEA Safety Standards Series No. SSG-50, Operating Experience Feedback for Nuclear Installations [27].

7.5. The operating organization should identify and implement design and procedural recommendations on the basis of initial and periodic safety assessments within a reasonable time if conditions of low safety margin to external hazard mitigation and cliff edge effects are identified.

7.6. In the periodic updating of hazard management processes and procedures, the operating organization should consider and address structures, systems and components important for hazard prevention, protection and mitigation, including portable emergency equipment and passive design features. The effect of ageing of structures, systems and components should also be taken into account.

7.7. Procedures, training, drills and exercises for hazard management should be periodically validated to ensure that they remain consistent with updated design assumptions or design bases from safety assessments or safety analysis. Any changes in the procedures or in the use of the procedures should be communicated to all personnel involved and, if necessary, reflected in the training programme.

7.8. Strategies for coping with hazard impact should be examined and updated if there are any changes to the civil infrastructure around the plant site. Such changes include changes in the contact information of external organizations, in regional population sizes and the proximity of these populations to the site, in electrical grid interfaces, in transportation routes and in local industries.

7.9. The potential effects from changes in hazards should be identified and updated on the basis of the results of the periodic site hazard reassessment and the periodic safety assessment, as needed. Recommendations on the periodic update of information on the potential impacts of climate change are provided in IAEA Safety Standards Series No. SSG-18, Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations [28]. Additional considerations might be needed for multiple unit sites. For example, a change in the anticipated highest speed of extreme winds might affect the evaluation of the potential loss of off-site power for multiple units sharing the same switchyard. In this case, it is also necessary to evaluate the operating state of all units sharing the switchyard, for example if one unit is undergoing an outage while the other is in full-power operation.

7.10. Modifications to the design or operation of the plant during its lifetime (with regard to both equipment and organization) should be reflected in hazard management. Hazard management processes and procedures should be reviewed and updated following any plant modification.

7.11. If proposed solutions to potential hazard impacts are not implemented within a reasonable time, a technical justification for not implementing the solutions should be provided, and this justification should be reviewed and documented by the operating organization. The technical justification should describe any compensatory features provided to maintain an acceptable level of defence in depth, where applicable. The proposed solutions should also include the effect on structures, systems and components important to safety while the modification to the plant is being carried out.

8. CONTROL OF MATERIALS AND HOUSEKEEPING IN HAZARD MANAGEMENT

8.1. Control of materials and housekeeping can impact the progression of hazards and their consequences.

8.2. Hazard management should include specific plant walkdown procedures to be conducted periodically, as well as before and after an event. The results of these walkdowns should be properly documented. These walkdowns should ensure that the structures, systems and components needed for prevention, protection and mitigation of hazards and for coping with the impact of hazards are in place and kept operational. Some examples of walkdowns are the following:

(a) Ensuring that non-essential flammable materials, including ignition sources (e.g. flame cutting, welding), are removed from the vicinity of activities;
(b) Ensuring that fire extinguishing equipment is present on the site and operable;
(c) Ensuring that culverts are kept clear, as they can have a significant impact on the ability of the site drainage systems to dewater the site;
(d) Ensuring that loose materials (especially heavy objects) are cleared away or tied down, as they could create airborne missiles if extreme winds occur.

Some of these actions are of particular importance when an external hazard (e.g. extreme winds, flooding) is forecast, but proper housekeeping is required to be in effect at all times, even if some actions are particularly important only at times when an external hazard is forecast (see Requirement 28 of SSR-2/2 (Rev. 1) [1]). Further examples of actions that need to be taken and checked during walkdowns are given in Appendices I and II.

8.3. Hazard management should identify the measures needed for the management of materials and enhanced housekeeping in accordance with Requirement 28 of SSR-2/2 (Rev. 1) [1].

8.4. Control of materials at the various working areas should be enhanced at times of increased risk, for example if a hazardous event is predicted.

8.5. Housekeeping procedures for working areas should include specific activities to increase resilience to hazards by protecting essential areas and equipment.

8.6. Housekeeping should be enhanced at different times throughout the lifetime of the nuclear power plant, including periods of increased risk (e.g. just before returning from an outage or after the implementation of a modification).

9. MAINTENANCE, TESTING, SURVEILLANCE AND INSPECTION OF HAZARD PREVENTION, PROTECTION AND MITIGATION MEASURES

9.1. In accordance with Requirement 31 of SSR-2/2 (Rev. 1) [1], the operating organization is required to establish and implement a comprehensive programme to perform maintenance, testing, surveillance and inspection of hazard prevention, protection and mitigation measures. Further recommendations on such programmes are provided in SSG-74 [19].

9.2. The maintenance of design features for hazard prevention, protection and mitigation should be included in surveillance programmes. The operating organization should perform regularly scheduled inspections and maintenance activities to preserve the integrity and functional availability of all structures, systems and components important to safety designed for hazard prevention, protection and mitigation.

9.3. The operating organization should develop and maintain a list of hazard protection measures for the site and plant and should implement maintenance, testing, surveillance and inspection activities to ensure availability of these measures. The conditions for the use of these hazard protection measures should be documented. If the protection measures are derived from the safety analysis, the conditions for the use of the hazard protection measures should be set in accordance with the results or assumptions of the analysis. If these conditions cannot be met, alternative measures should be specified and implemented to maintain an adequate level of safety (see para. 9.5), and the time allowed to complete these alternative measures should be indicated.

9.4. The maintenance, testing, surveillance and inspection for the site and plant should include general hazard protection measures as well as measures for protection against specific hazards. Hazard protection and mitigation features that should be inspected, maintained and tested include the following:

(a) Hazard detection and alarm systems;
(b) Communication systems for use during the occurrence of a hazard;
(c) Emergency lighting systems;
(d) On-site mobile equipment and features for mitigating hazard effects (e.g. emergency vehicles, submersible pumps, mobile diesel generators with adequate fuels);

(e) Engineered structures, fittings and barriers (e.g. fire doors, watertight doors, dampers, penetrations);
(f) Access and escape routes for hazard response personnel;
(g) Respiratory protective equipment and other personal protective equipment.

9.5. Maintenance, testing, surveillance and inspection activities can be conducted during outages or on-line states of the plant. The on-site hazard protection measures should be complemented by alternative measures so that an appropriate level of defence in depth is continuously maintained during the off-line states of those original measures owing to maintenance, testing, surveillance and inspection. Some examples of alternative measures are the following:

(a) Sustaining fire barriers, fire hazard monitoring equipment and firefighting equipment (e.g. assigning a fire watch[8] during fire sensor repairs, securing water lines or fire extinguishers while fire water systems are partially isolated);
(b) Ensuring that flood doors or flooding hazard mitigation measures are not compromised by a lack of sealing on drill holes or by a lack of alternative barriers during maintenance;
(c) Deploying accident management equipment for spray water for the reactor or for the spent fuel pool and electrical power supply;
(d) Deploying emergency response personnel.

9.6. Special consideration should be given to off-site equipment dedicated to hazard mitigation, such as the following:

(a) Protective barriers and other hazard protection measures not located on the site (e.g. dykes). Such protective barriers and hazard protection measures might not be under the direct control of the operating organization, and their maintenance might therefore necessitate special arrangements.
(b) Equipment provided by external organizations or stored in an off-site location, and additional off-site engineered equipment that might be used in hazard mitigation measures and strategies for coping with hazard impact. Such equipment should be included in maintenance, testing, surveillance and inspection procedures.

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[8] A fire watch is one or more persons responsible for providing additional monitoring of plant activities or areas for the purpose of detecting fires or identifying activities and conditions that present a fire hazard; these persons are trained in identifying conditions or activities that present potential fire hazards, as well as in the use of firefighting equipment and the proper fire notification procedures.

(c) Hazard mitigation equipment. For predictable or partially predictable hazards, the operating organization should consider pre-event inspection and/or testing of this equipment to ensure its availability when the event occurs.

9.7. The operating organization should consider additional combustible materials and ignition sources during the maintenance and modification activities (see Appendix I, paras I.23–I.41).

10. TRAINING OF PERSONNEL ON HAZARD MANAGEMENT

10.1. Before starting work, all personnel of the operating organization and any contractor personnel temporarily assigned to the plant should receive training on hazards that might affect the operation of the plant. Training of personnel is required to be performed in accordance with Requirement 7 of SSR-2/2 (Rev. 1) [1]. Recommendations on the training of personnel are provided in SSG-75 [20].

10.2. Specialized training in hazards should be established for those personnel involved in operations, maintenance activities and hazard mitigation activities at the plant, including contractor personnel temporarily assigned to the plant, where applicable. The level of training provided should be tailored to the role undertaken by the individual or group; different training courses can be provided to different individuals or groups.

10.3. In accordance with Requirement 7 of SSR-2/2 (Rev. 1) [1], the operating organization is required to ensure that personnel have adequate skills commensurate with their roles in hazard management and are familiar with the procedures to be followed.

10.4. Training should be sufficient to ensure that individuals (a) understand the significance of their duties and the consequences of errors arising from misconceptions or lack of diligence and (b) understand and follow the evolution of the plant status, including unanticipated evolution of the hazards. Records of training and qualification should be maintained. Also, training materials should be updated, as appropriate, and should reflect the current plant configuration and hazards.

10.5. The training of all personnel on hazard management should include the following topics:

(a) Hazard management approaches at the plant;
(b) General awareness of specific hazards (see para. 10.7);
(c) Roles and responsibilities of personnel for hazard management before, during and after events;
(d) Recognition of audible and visual alarm signals, including fire alarms, tsunami warnings, and other alarms as applicable to the site;
(e) Exits and emergency evacuation routes;
(f) The need to delay or discontinue certain plant activities if specific external hazards — such as extreme ambient temperatures, flooding or extreme winds — are predicted;
(g) The means of reporting hazards and actions to be taken to make work safe;
(h) The different types of portable or resilience equipment provided and their use in mitigating hazard effects in the initial stage; such equipment might include firefighting equipment, flood barriers and communication equipment (e.g. satellite phones).

10.6. The training for personnel who authorize relevant work activities and for personnel who may be assigned duties for hazard prevention, protection or mitigation should cover the following topics:

(a) The importance of maintaining the integrity and operability of hazard prevention, protection and mitigation features (both passive and active) and performing regularly scheduled inspections, routine and emergency maintenance of equipment, and periodic functional tests of equipment and systems;
(b) The design and operation of the specific hazard prevention, protection and mitigation features installed in the plant to permit effective maintenance of equipment for operability, and the results and assumptions of the hazard analysis, if applicable;
(c) The significance of planned design changes and plant modifications with respect to hazards, including those changes and modifications not affecting equipment qualification and safety classification, as well as direct and indirect impacts on safety and any effects on the integrity or operability of the hazard prevention, protection and mitigation features (both passive and active) as a result of these modifications;
(d) Familiarization with the physical location of structures, systems and components important to safety, preferably through a plant walkdown;

(e) Familiarization with the physical location of hazard prevention, protection and mitigation features of the plant;

(f) Knowledge of the design and testing requirements of hardware for hazard protection features and knowledge of the objectives for those features, as specified in the safety assessment or similar documentation, to ensure that the personnel responsible for the review of plant modifications recognize issues that might have implications for hazard prevention, protection and mitigation features.

10.7. Familiarization and training for personnel responsible for the initiation or authorization of relevant work activities should cover specific topics regarding hazard prevention, protection or mitigation, including the following:

(a) For fire hazards:
  - How to control combustible materials and ensure that area limitations on fire loads[9] are met;
  - Awareness of potential ignition sources, and their limitation and control, for example by using a special system of permits for hot work[10];
  - Maintenance, testing, surveillance and inspection of passive fire protection measures, including fire barriers and their active elements such as doors, dampers and other penetrations, as well as consideration of the corresponding relevant working practices;
  - Maintenance, testing, surveillance and inspection of fire detection, alarm and reporting means, including actions to be taken;
  - Recognition of audible and visual fire alarm signals;
  - Maintenance, testing, surveillance and inspection of means of access and escape as well as emergency evacuation routes in the event of fire;
  - The designated assembly point for evacuation;
  - Prevention of adverse effects from flooding caused by fire extinguishing media;

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[9] The fire load is the sum of the calorific energies calculated to be released by the complete combustion of all the combustible materials in a space, including the facings of the walls, partitions, floors and ceiling.

[10] Hot work is work having the potential for causing fire, particularly work involving the use of open flames, soldering, welding, flame cutting, grinding or disc cutting. This might include work involving the use of heating devices, volatile organic solvents or electric motor-powered tools.

— Manual firefighting capability and automatic fire extinguishing with the different types of fire extinguishing systems and equipment provided, and their use, maintenance, testing, surveillance and inspection;
— The fire safety policy at the plant;
— Awareness of specific fire hazards (including combined hazards), as well as of limitations on the fire load and, where necessary, associated radiation protection concerns;
— The control of combustible materials and ignition sources and the potential impact of the materials and the sources on the permissible fire load in an area;
— The hazards associated with hot work activities, such as cutting or welding, that could be a potential ignition source;
— The stipulations of the work permit system, the specific situations in which a fire watch is necessary, and the risk of introducing potential ignition sources into fire compartments[11] containing structures, systems and components important to safety;
— Instructions on work implementation and general fire safety training so that the personnel can readily recognize various fire hazards at the plant and can understand the implications of introducing combustible materials or ignition sources into areas containing components important to safety;
— Controls on hot work and the significance of hot work for fire safety, as well as instructions and procedures for taking appropriate additional or alternative fire prevention, protection and mitigation measures to sustain protective barriers (e.g. fire watches for fire detection; safety measures in confined spaces; area ventilation systems; inspection, maintenance and repair of fire extinguishing features).

(b) For internal flooding:
— Reliable functioning of barrier elements (e.g. doors, other penetrations) in walls, floors and ceilings and of drainage systems for protection against adverse effects from the spread of flooding media in the event of internal flooding, including their control, inspection and maintenance;
— Floor area control with respect to temporary storage;
— The ability to respond to (e.g. detect, isolate) leaks in diverse locations within the time necessary to complete these actions;
— Pumping of water from flooded areas or compartments;
— Operation of equipment in flood conditions;
— The results and assumptions of the internal flooding hazard analysis.

[11] A fire compartment is a building or part of a building that is completely surrounded by fire resistant barriers (i.e. all walls, the floor and the ceiling).

(c) For flooding external to the buildings:
- Maintenance, testing, surveillance and inspection of doors, gates and penetration seals of buildings that need to remain watertight to withstand external flooding;
- Awareness of extreme precipitation and flood warnings and the approach to taking these into account in protection against external flooding.

(d) For seismic hazards:
- The significance of housekeeping to avoid extraneous debris or loose items;
- Awareness of the potential for collapse of temporary platforms and scaffolds (in particular inside buildings and close to structures, systems and components important to safety) and the need to adequately secure such temporary structures;
- Information on drills and exercises, including drills in prompt decision making, notification, communication with external organizations, shutdown, work control, evacuation and other mitigatory actions in line with the on-site emergency plan (see paras 3.11 and 10.10).

(e) For extreme winds and other meteorological hazards:
- Awareness of extreme precipitation, storm and other meteorological warnings and the approach to taking these into account in protection against extreme winds and other meteorological hazards;
- Awareness of the hazards associated with items not adequately fixed against extreme winds and with heavy machinery that might be in danger of collapsing and the potential that these items might become wind-borne missiles, as well as the need for restrictions on vehicle parking and equipment storage;
- The work control and evacuation procedure, in accordance with the meteorological alert level;
- Awareness of the potential for collapse of temporary platforms and scaffolds and the need to adequately secure such temporary structures;
- Notification of and communication with external organizations.

(f) For explosion hazards:
- Active and passive protection systems (e.g. gas detectors, blast doors, blowout panels, room and area ventilation systems);
- Explosion detection, alarm and reporting means, and actions to be taken;
- Recognition of audible and visual explosion alarm signals;
- Significance of the control of flammable gas pipes;
- The hazards associated with activities using flammable or compressed gas or involving battery charging.

10.8. Certain activities might lead to additional risks involving internal or external hazards; therefore, familiarization and training for personnel in charge of authorizing or performing such activities should be provided. Some examples of these types of additional risk are provided in para. 10.9.

10.9. Personnel in charge of authorizing who initiates work activities involving the handling or management of radioactive material should be trained to ensure they are aware of relevant items, including the following:

(a) Description of the categories of radioactive material; labelling, marking, placarding, and packaging and segregation requirements; the purpose and content of the radioactive material transport documents; and the available emergency response documents;
(b) The ambient conditions that form part of the safe operating envelope for individual fuel or waste packages and the requirement to ensure that these conditions are not exceeded during handling;
(c) The means by which the site receives and communicates warnings or information on forecasts for predictable external hazards that could affect the ability of personnel to perform the fuel or waste handling safely (e.g. external flooding, meteorological and other natural hazards);
(d) Actions to take after the occurrence of a seismic event during fuel or waste handling to verify that the integrity of the transport package has not been compromised; the receiving facility and structures, systems and components have not been unacceptably affected; and the handling process can be successfully completed.

EXERCISES AND DRILLS

10.10. Periodic exercises and drills should be sufficiently realistic so that the personnel develop the capability to cope with and respond to situations that might occur in the event of hazards. Exercises or drills should simulate a time period long enough to realistically represent the plant response and associated information transfer, and, if necessary, they should be developed to practise shift changes and to simulate the strategies for coping with hazard impact. For exercises on external hazards in particular, it should be considered that such hazards might simultaneously or sequentially affect multiple units at the site.

10.11. Training should address the implementation of response actions under adverse environmental conditions and, if necessary, the influence of stress on the anticipated behaviour of the personnel.

10.12. Results from exercises and drills should be systematically evaluated and documented to provide feedback for the improvement of the training programme and, if applicable, the procedures and instructions (see para. 7.7).

10.13. Specifically, for fire hazards, para. 5.24 of SSR-2/2 (Rev. 1) [1] states that "Periodic joint fire drills and exercises shall be conducted to assess the effectiveness of the fire response capability." Drills or exercises should be performed with participating site personnel and, as appropriate, off-site firefighters (see Appendix I).

Appendix I

TECHNICAL ASPECTS TO BE CONSIDERED IN HAZARD MANAGEMENT FOR PROTECTION AGAINST INTERNAL HAZARDS

I.1. This appendix provides recommendations on elements of hazard management for specific internal hazards in addition to the general recommendations for mitigating and coping with internal hazards provided in Section 4.

INTERNAL FIRES

Defence in depth

I.2. To ensure adequate fire safety in a nuclear power plant, an appropriate level of defence in depth should be maintained throughout the lifetime of the plant, through the fulfilment of the following three principal objectives:

(a) Preventing fires from starting;
(b) Detecting and extinguishing quickly those fires that do start, thus limiting the damage;
(c) Preventing the spread of those fires that have not been extinguished, thus minimizing their effects on essential plant functions.

I.3. By satisfying these three objectives, the following should be ensured:

(a) The probability of a fire occurring is reduced to as low as reasonably practicable.
(b) Structures, systems and components are adequately protected to ensure that the consequences of a single fire will not result in the loss of capabilities of those structures, systems and components to perform their intended safety functions, taking into account the effects of the worst single failure of active fire protection features. Further recommendations on the safety classification of structures, systems and components for fire protection systems are provided in IAEA Safety Standards Series No. SSG-30, Safety Classification of Structures, Systems and Components in Nuclear Power Plants [29].

I.4. These three objectives of defence in depth should be achieved through a combination of design, installation and operation of fire prevention and protection features; management of fire safety; fire prevention and protection measures; quality assurance; and emergency arrangements. These aspects are addressed in the following paragraphs. Recommendations on design related aspects of internal fire hazards are provided in SSG-64 [4].

Fire safety management

I.5. The operating organization should clearly define in writing the responsibilities of all personnel involved in fire prevention and protection and in firefighting activities and fire mitigation measures.

I.6. Plant personnel engaging in activities relating to fire safety should (a) be appropriately qualified and trained so as to have a clear understanding of their specific areas of responsibility and how these might interface with the responsibilities of other individuals and (b) have an understanding of the potential consequences of errors. Also, external personnel (e.g. off-site firefighters) engaging in activities relating to fire safety should be appropriately trained so as to have a clear understanding of the specific nature of relevant nuclear power plants.

I.7. To foster continual improvement, plant personnel and external personnel (e.g. off-site firefighters) should be encouraged and trained to adopt a rigorous approach to their firefighting activities and responsibilities and a questioning attitude in the performance of their tasks.

I.8. The cause of any fire or of the failure or spurious operation of fire protection features that has the potential to affect safety should be determined, and corrective actions should be taken to prevent a recurrence. Operating experience from fires at other plants and its potential implications for fire prevention and protection should be considered. Communication should be maintained and information should be exchanged between the operating organizations of different nuclear power plants (and with the regulatory body) on nuclear safety related aspects of fire safety.

Fire prevention and protection

I.9. Procedures should be established to minimize the presence of combustible materials (i.e. the fire load) and the amount of ignition sources in areas containing items important to safety and in adjacent areas that might present a risk of exposure to fire for items important to safety.

I.10. Effective procedures for maintenance, testing, surveillance and inspection should be prepared and implemented throughout the lifetime of the plant, with the objective of ensuring continued minimization of the fire load and the reliability of the features in place for detecting, extinguishing and mitigating the effects of fires, including established fire barriers. Fire mitigation measures should be identified and designed in accordance with their impact on safety (see SSG-30 [29]). The operating organization should address the identified impact of the implemented measures for mitigating the effects of fires and of active protection means (for fire detection and suppression) and passive protection means (e.g. fire barriers) on safety.

Organization and responsibilities

I.11. The operating organization should establish an on-site group with the specific responsibility of ensuring the continued effectiveness of the fire safety arrangements. Responsibility for coordinating fire safety activities should be assigned to an individual, generally referred to as the fire safety coordinator.

I.12. The fire safety coordinator should retain the responsibility for ensuring that all fire safety activities and functions necessary for safety are effectively coordinated to achieve the objectives of fire prevention and protection.

Fire hazard analysis

I.13. A comprehensive fire hazard analysis should be performed for the plant to achieve the following (see SSG-64 [4]):

(a) Demonstrate the adequacy of the fire protection measures in place (both passive and active) to protect areas containing systems, structures and components important to safety for all plant states;
(b) Identify any specific areas where fire protection measures are inadequate and where corrective measures are necessary;
(c) Provide a technical justification for deviation from the recommended practices in cases where no corrective measures are taken (see para. I.15).

The fire hazard analysis should be updated regularly over the lifetime of the plant and in case of any plant modifications. Further recommendations on the safety classification of fire protection systems are provided in SSG-30 [29].

Impacts of plant modifications on fire safety

I.14. Any modification that might affect, directly or indirectly, the fire protection measures in place — including the integrity of fire barriers and the manual firefighting capability — should be subject to a procedure for controlling modifications. This procedure should provide assurance that there will be no detrimental effects on the fire protection measures in place or on the provision of an effective manual firefighting capability in those areas for which fire protection measures are identified as necessary to maintain safety.

I.15. If a technical justification for deviation from the recommended practice is provided when the fire hazard analysis is updated, this justification should include a description of the plant modifications that would be necessary to follow recommended practice and the reasons why it is not reasonably practicable to implement such modifications. The technical justification should also describe any compensatory features provided to maintain an acceptable level of safety, where applicable.

I.16. A review of implications for fire safety should be performed for the following modifications to the plant, if necessary, as part of the update to the fire hazard analysis:

(a) Modifications to fire protection features;
(b) Modifications to protected items important to safety or systems that could adversely affect the performance of the fire protection features;
(c) Any other modification that could adversely affect the required performance of fire protection features, including changes in the fire load from the fire load identified in the fire hazard analysis.

I.17. Operating licences issued to nuclear power plants usually include a requirement for approved, written procedures to be established and implemented for controlling modifications to structures, systems and components. All proposed plant modifications should be scrutinized for their potential effect on fire loads and fire protection features, since a modification involving structures, systems and components that are not important to safety could conceivably change a fire load or could degrade a fire protection feature whose primary purpose is to protect safety systems.

I.18. A formal review system to evaluate the impacts of modifications on fire safety should be incorporated into the overall modification procedure. Alternatively, a separate procedure should be established and implemented specifically for reviews for fire safety. Modifications should not be commenced until the review has been completed.

I.19. The personnel assigned the responsibility of performing such reviews for issues of fire safety should be suitably qualified to evaluate the potential effect of any modification on fire safety and should have sufficient authority to prevent or suspend modification work, if necessary, until any issues identified have been satisfactorily resolved.

I.20. Plant modifications should only be carried out in accordance with a work permit issued by a person who is competent in and knowledgeable of the implications for fire safety and who is authorized to issue such permits. It also should be ensured that nuclear security personnel are notified of modifications to the plant's physical layout.

I.21. If a modification necessitates the removal from service of any of the fire protection features, careful consideration should be given to the consequent reduced level of protection of items important to safety or of hazard prevention, protection and mitigation features, and appropriate temporary arrangements should be made to maintain adequate protection against fire. On completion of the modification, the plant as modified should be inspected to confirm its compliance with the modified design. In the case of an active fire protection system, the modified system should be commissioned and the plant as modified should be placed into or returned to normal service, as applicable.

I.22. The fire hazard analysis should be reviewed and updated to reflect the modification, as appropriate.

Control of combustible materials and ignition sources

I.23. Administrative procedures should be established in writing and implemented for effective control of combustible materials throughout the plant. The administrative procedures should establish controls for the delivery, storage, handling, transport and use of flammable or combustible solids, liquids and gases. Consideration should be given to the prevention of fire related explosions within or adjacent to areas containing items important to safety. For such areas, the procedures should establish controls for combustible materials associated with normal plant operations and those that might be introduced in activities relating to maintenance or modifications.

I.24. Written procedures should be established and enforced to minimize the amount of transient (i.e. non-permanent) combustible materials, particularly packaging materials, in areas containing items important to safety. Such materials should be removed as soon as the activity is completed (or at regular intervals) or should be temporarily stored in approved containers or storage areas.

I.25. The total fire load in each area containing items important to safety should be maintained as low as reasonably practicable, with account taken of the fire resistance rating of the fire compartment boundaries. Records should be maintained that document the estimated or calculated actual fire load as well as the defined maximum permissible fire load for each fire compartment. In addition, combustible materials allowed in each area, in terms of nature, location and maximum amount, should be defined and documented.

I.26. The use of combustible materials in the furnishings of the plant should be minimized. Combustible materials should not be used for decorative reasons or other non-essential reasons in areas containing items important to safety.

I.27. Administrative controls should be established and implemented to ensure that areas containing items important to safety are inspected periodically to (a) evaluate the general fire load and the plant housekeeping conditions and (b) ensure that means of access and escape routes for manual firefighting are not blocked. Administrative controls should also be established and implemented to ensure that the actual fire load is kept within permissible limits.

I.28. Administrative procedures should be established and implemented to provide effective control of temporary fire loads in areas containing items important to safety during maintenance and modification activities. These procedures should cover flammable or combustible solids, liquids and gases; their confinement; and their storage locations in relation to other hazardous materials, such as oxidizing agents. These administrative procedures should also include a procedure for issuing work permits that necessitate in-plant review and approval of proposed work activities before the start of work to determine the potential effect on fire safety. The on-site personnel responsible for reviewing work activities for the potential for creation of temporary fire loads should determine whether the proposed work activity is permissible and should specify any additional fire protection measures needed (e.g. the provision of portable fire extinguishers, the assignment of a fire watch).

I.29. Administrative procedures should be established and implemented to control the storage, handling, transport and use of flammable and combustible solids and liquids in areas containing items important to safety.

I.30. Controls for solids should take into account the following:

(a) The use of combustible materials (e.g. wooden scaffolding, polymer joints) should be restricted. Where wooden materials are permitted, they should be chemically treated or coated so as to be fire retardant.
(b) The storage of combustible materials such as papers, personal protective equipment, charcoal filters and dry unused ion exchange resins should be restricted; any large stocks of such materials should be placed in a designated storage area, with appropriate fire barriers and fire protection measures provided.
(c) The storage of all other flammable or combustible materials should be prohibited.

I.31. Controls for liquids should take into account the following:

(a) The amounts of flammable or combustible liquids introduced into fire compartments during maintenance or modification activities should be limited to the amount needed for daily use. Suitable fire protection measures, such as the provision of portable fire extinguishers, should be taken.
(b) Approved containers or dispensers should be used whenever possible for the transport and use of flammable liquids. Openings in containers should be fitted with spring loaded caps. Transport of flammable liquids in open containers should be prohibited.
(c) If it is necessary to store small amounts of flammable liquids within a working area, cabinets of an approved design for flammable liquids should be used.
(d) All containers of flammable liquids should be clearly and prominently labelled to indicate their contents.
(e) Stores of large quantities of flammable liquids should be located and protected such that they do not compromise safety. Such bulk storage areas should be separated from other plant areas by fire rated compartmentation or by spatial separation, with suitable fire protection measures taken.
(f) Warning signs should be placed at storage areas for flammable liquids.

I.32. Administrative procedures should be established and implemented to control the delivery, storage, handling, transport and use of flammable gases throughout the plant. The procedures should ensure the following:

(a) Cylinders of compressed gases that sustain fires, such as oxygen, are properly secured and are stored separately from flammable gases and away from combustible materials and ignition sources.
(b) Where a supply of flammable gas is needed inside a building for permanent use, it is supplied from cylinders or a bulk storage area safely located outside the building in a dedicated storage area such that a fire affecting the storage area would not compromise safety.

I.33. Administrative procedures should be established and implemented to control potential ignition sources throughout the plant. The procedures should include controls to achieve the following:

(a) Restrict personnel smoking to designated safe areas and prohibit personnel from smoking in all other areas;
(b) Prohibit the use of open flames for testing heat or smoke sensing devices (e.g. fire detectors) or for leak testing;
(c) Prohibit the use of portable heaters, cooking appliances and other such devices in areas containing items important to safety;
(d) Limit the use of temporary wiring;
(e) Limit the testing of portable electronic equipment.

I.34. Administrative procedures should be established and implemented to control maintenance and modification activities that necessitate the use of a potential ignition source or that might themselves create an ignition source. The performance of such work should be controlled by means of formal written procedures (i.e. the work permit system or a special system of permits for hot work). In the permit system adopted, procedures should be established to cover management, supervision, authorization and performance of the work; inspection of the work area; assignment of a fire watch (if stipulated); and access for firefighting. All personnel involved in the preparation, issuing and use of permits for hot work should be instructed in the proper use of the permit system and should have a clear understanding of its purpose and application. Whether or not a fire watch is provided, at least one person engaged in hot work should be trained in the use of any fire protection features provided.

I.35. In areas containing items important to safety, work that involves the use of a potential ignition source or that might create ignition sources should be permitted only after consideration of the possible consequences for safety. For example, such work might be prohibited from occurring simultaneously on functionally redundant items important to safety or in the areas containing such items.

I.36. Procedures should be established to ensure that before any hot work is attempted the immediate work area and adjacent areas are inspected for the presence of combustible materials and that the operability of necessary fire protection measures is confirmed. If the configuration and design of the work area might permit the spread of sparks or slag beyond the initial work area, spaces both above and below the work area should be checked, and any combustible materials should be either removed to a safe area or suitably protected.

I.37. During hot work, regular inspections should be performed to ensure that the conditions of the permit are observed, that there are no exposed combustible materials present and that the fire watch is on duty (if a fire watch has been stipulated in the permit).

I.38. In cases where the permit for hot work identifies the need for a fire watch, the following procedures should be followed:

(a) The fire watch should be on duty in close proximity before any hot work is attempted, the work should be stopped if the fire watch leaves the work area, and the fire watch should remain in the work area for an appropriate period after open flame work is completed.
(b) While the work is in progress, the fire watch should perform no other duties.
(c) Suitable dedicated firefighting equipment should be readily available, and means should be provided by which additional assistance can be readily obtained, if necessary.
(d) Adequate access and escape routes for firefighters should be maintained.

I.39. Any equipment or vehicle in use in areas in which a flammable gas could be released should be appropriately qualified for use in explosive atmospheres.

I.40. The use of compressed gas cylinders for cutting or welding operations or other hot work should be controlled by a system of work permits.

I.41. Warning signs should be placed at the entrances to areas containing combustible materials to warn personnel of restrictions or access control measures and of the necessity of permanently controlling ignition sources.

Maintenance, testing, surveillance and inspection of fire protection means

I.42. The maintenance, testing, surveillance and inspection programme should cover the following fire protection means:

(a) Passive fire rated compartment barriers and structural elements of buildings, including the seals of barrier penetrations;
(b) Fire barrier elements with active functions, such as fire doors and fire dampers;
(c) Separating or protective elements, such as fire retardant coatings and qualified cable wraps, and fire detection and alarm systems including fire detectors, flammable gas detectors and their electrical support systems;
(d) Fire extinguishing systems;
(e) Fire water supply system, including a water source, a supply and distribution pipe, sectional and isolation valves, and fire pump assemblies;
(f) Gaseous and dry powder fire extinguishing systems;
(g) Portable fire extinguishers;
(h) Other manual firefighting equipment, including emergency vehicles;
(i) Smoke and heat removal systems and air pressurization systems;
(j) Emergency lighting systems;
(k) Communication systems for use in fire incidents;
(l) Respiratory protective equipment and other personal protective equipment;
(m) Access and escape routes;
(n) Emergency procedures.

Manual firefighting capability

I.43. A firefighting strategy should be developed for each area of the plant containing items important to safety. These strategies should provide information to supplement the information provided in the general plant emergency plan. The strategies should provide all appropriate information needed by firefighters to use safe and effective firefighting techniques in each fire compartment and outside areas of the plant containing items important to safety. The strategies should be kept up to date and should be used in routine classroom training and in actual fire drills at the plant. The firefighting strategy developed for each fire compartment and outside areas of the plant containing items important to safety should cover the following:

(a) Access and escape routes;
(b) Locations of structures, systems and components important to safety;
(c) Fire load per floor area;

(d) Particular fire hazards, including the possibly reduced capability for firefighting due to fire hazard combinations, in particular with external hazards (e.g. seismic or extreme wind hazards);
(e) Special radiological, toxic, high voltage and high pressure hazards, including the potential for explosions;
(f) Fire protection features provided (both passive and active);
(g) Restrictions on the use of specific fire extinguishing media because of concerns about criticality safety or other particular concerns, and the alternative extinguishing media to be used;
(h) Locations of heat or smoke sensitive items important to safety;
(i) Location of fixed and portable extinguishing equipment;
(j) Water supplies for manual firefighting;
(k) Confinement of fire water runoff from firefighting activities;
(l) Communication systems (i.e. which do not affect items important to safety) for use by firefighting personnel;
(m) Nuclear security features and notification procedures for nuclear security personnel;
(n) Consideration of unacceptable effects of firefighting (e.g. the use of water or other extinguishing media) on structures, systems and components important to safety (e.g. measuring converters on the bottom level of the reactor annulus), when fire and the subsequent unacceptable effect are defined as a credible combination of hazards according to SSG-64 [4].

I.44. The plant documentation should provide a clear description of the manual firefighting capability provided for those areas of the plant containing items important to safety. The manual firefighting capability might be provided by suitably trained and equipped on-site firefighters, by a qualified off-site service or by a coordinated combination of the two, as appropriate for the plant and in accordance with national practice.

I.45. If reliance is placed on off-site response, a well balanced notification protocol for reliability and rapidness should be established between the operating organization and off-site firefighters. Designated plant personnel in each shift should be assigned the responsibility of coordinating and liaising with the off-site firefighters and of establishing a clear line of authority at the fire scene. Appropriate plant personnel should be designated even in situations in which the off-site response is supplementary to a primary response by qualified on-site firefighters. A possible delay in the off-site response should be taken into account in the fire hazard analysis.

I.46. Where full or partial reliance is placed on off-site resources for manual firefighting capability, there should be proper coordination between the plant personnel and the off-site response group to ensure that the latter is familiar with the hazards of the plant. The responsibilities and lines of authority for manual firefighting personnel should be documented in a firefighting plan.

I.47. If an on-site firefighting organization is established to provide manual firefighting capability, the firefighters' organization, minimum staffing level, equipment (including self-contained breathing apparatus) and training should be documented, and their adequacy should be confirmed by a competent person.

I.48. Members of the on-site firefighting organization should be physically capable of performing firefighting duties and should attend a formal programme of firefighting training prior to assignment to the on-site firefighters. Regular training (i.e. routine classroom training, firefighting practice and fire drills) should be provided for all on-site firefighters. Special training should be provided for firefighters in leadership positions to ensure that they are competent to assess the potential safety consequences of a fire and provide advice to control room personnel.

I.49. If manual firefighting represents the primary means of fire protection, radiation protection of firefighters and other personnel should be ensured.

Fire related training of plant personnel

I.50. All plant personnel and contractor personnel temporarily assigned to the plant should receive training in plant fire safety, including their responsibilities in fire incidents, before starting work at the plant. These topics for training are provided in para. 10.7.

I.51. Selection and appointment procedures for plant personnel should establish minimum initial qualifications for all personnel involved in fire safety functions and activities that might affect safety. These minimum qualifications should be based on an evaluation of the necessary education, technical competence and practical experience for the job concerned.

Quality assurance for matters relating to fire safety

I.52. Fire protection features (including preventive features) are not generally classified as hazard prevention, protection and mitigation features; thus, they might not be subject to the rigorous qualification requirements and associated quality assurance programme applied to hazard prevention, protection and mitigation features. However, fire has the potential to cause multiple systems to fail, and therefore the operating organization should apply an appropriate level of quality assurance to active and passive fire protection measures in accordance with their safety significance.

INTERNAL EXPLOSIONS

I.53. The operating organization should consider various explosion sources when addressing the prevention, detection and mitigation of internal explosions. Potential sources of internal explosions might be related to the use or generation of explosive gases and compressed gases. There is also a potential for dust or oil mist explosions, although these are generally less likely. Additionally, events leading to an energy release similar to an explosion might come from high energy arc flashes in electrical equipment. Explosion events might also occur in conjunction with other hazards (e.g. fire), and a release of fluids stored at high pressure can result in significant overpressure events that have effects similar to explosions.

I.54. The potential formation of an explosive atmosphere should be avoided or limited using non-flammable liquids, such as water based solvents, and by applying suitable processes such as operating contamination monitors with inert gases and recombining hydrogen emissions from battery charging.

I.55. Internal fires and internal explosions are similar hazards and, in developing the management for internal explosions, the recommendations provided for internal fires (see paras I.2–I.52) should be taken into consideration. For explosions, as with fires, there should be enhanced control over materials and operations during times of increased explosion risks.

I.56. Active and passive protection means (e.g. gas detectors, blast doors, blowout panels, room and area ventilation systems, venting safety devices) should be subject to the maintenance, testing, surveillance and inspection programmes identified in hazard management.

I.57. Operating procedures (e.g. area ventilation procedures, area or system isolation procedures) should be applied to prevent explosion events and post-explosion events.

I.58. Administrative procedures should be established and implemented to control the delivery, storage, handling, transport and use of flammable and explosive materials, including the types, quantities and locations of gases throughout the plant. The procedures should ensure the following:

(a) Containers of compressed gases that sustain fires, such as oxygen, should be properly secured and stored separately from flammable gases and away from combustible materials and ignition sources.
(b) Where a supply of flammable gas is needed inside a building for permanent use, it should be supplied from cylinders or from a bulk storage area safely located outside the building in a dedicated storage area such that a fire affecting the dedicated storage area would not compromise safety.

I.59. Control of ignition sources is a main preventive measure for internal explosions. Therefore, administrative procedures should be established and implemented to control maintenance and modification activities that necessitate the use of a potential ignition source or that might themselves create an ignition source. The performance of such work should be controlled by means of formal written procedures (i.e. the work permit system or a special system of permits for hot work). Flammable gases might have the potential to create explosive mixtures, which can cause an explosion if ignition sources are present.

I.60. In areas containing items important to safety, work that involves the use of a potential ignition or explosion source or that might create ignition sources should be permitted only after consideration of the possible consequences for safety. For example, such work might be prohibited from occurring simultaneously on functionally redundant components important to safety or in areas containing such components.

I.61. The operating organization should control or limit personnel access in areas where explosion hazards could occur, such as main and auxiliary transformer areas. The preventive measures for combustible materials, as described in paras I.23–I.41, should also be applied.

INTERNAL MISSILES

I.62. Potential missile sources are present at all nuclear power plants. The operating organization should ensure that the integrity of potential internal missile sources and of engineered structures is maintained so that internal missile generation and hazard propagation are prevented or unlikely and limited in extent, if the hazard occurs, and are mitigated before they affect essential plant or system functions.

I.63. Operating procedures should be developed and implemented for identified and characterized internal missile sources to prevent internal missile hazards; these operating procedures should include the following:

(a) Regular plant area walkdowns to detect missile hazards;
(b) Observation of personnel interacting with potential missile sources;
(c) Inspections of rotating machinery, including means to limit rotational speed and monitoring and surveillance measures;
(d) Regular inspections of turbine blades for degradation;
(e) Inspections of storage areas of high pressure gas bottles and of the integrity of the gas bottles themselves;
(f) In the areas where structures, systems and components important to safety are located, inspection of pressure vessels and of high energy valves to detect possible flaws (e.g. checking for the presence and good tightening of all bolts fastening the cap of the valves on their bodies, inspection of welds).

I.64. The operating organization should control or limit personnel access in areas where missile hazards could occur.

I.65. The operating organization should establish operating procedures that describe actions following early identification of missile hazards at the site. Early indications of a missile hazard might include output from vibration monitors or reports of unusual sounds. Indication that an event has occurred might come from direct observation of missile effects by personnel or from video monitoring of plant areas.

I.66. Operating procedures to be implemented after missile events should include actions such as plant walkdowns to determine the missile impact on the integrity and functionality of structures, systems and components important to safety.

I.67. Much of the protection provided against the effects of missile hazards is from basic layout decisions in design and from passive hazard protection such as engineered barriers. The passive features should be subject to the maintenance, testing, surveillance and inspection programmes identified in hazard management as well as to plant surveillance programmes (see Section 9).

I.68. The integrity of engineered structures and barriers affected by an internal missile hazard should be assessed.

PIPE BREAKS

I.69. Pipe breaks (or pressure part failure) are associated with a variety of resulting hazard phenomena, including pipe whip impacts, room pressurization, jet effects and flooding. The extent of each of these phenomena depends on the fluid involved and its temperature and pressure. In accordance with Requirements 10, 14, 24 and 31 of SSR-2/2 (Rev. 1) [1], the actions described in paras I.70–I.74 should be implemented to prevent pipe breaks and mitigate their potential impact.

I.70. The operating organization should ensure that the control of plant configuration for the plant piping is maintained at all times, including engineered structures designed to minimize the impact of pipe breaks. Periodic walkdowns of plant areas should be performed to confirm that the plant conditions correspond to those stated in the design, including identification of items that could hinder or make ineffective leak detection devices, proper closure of compartment doors and proper installation of protective covers. These periodic walkdowns should also include (a) inspections to identify general pipe and piping component degradations and steam and water leaks and (b) inspections of engineered barrier integrity, pipe whip restraints, pipe hangers, blast doors, blowout panels and drains.

I.71. The ageing management programme should incorporate the appropriate aspects of pipe integrity, including operating experience feedback regarding any new information on the potential degradation of comparable piping systems.

I.72. Maintenance, testing, surveillance and inspection programmes should ensure that any degradation of piping systems is detected and corrected in a timely manner, thereby preventing pipe failures. Movable engineered structures designed to minimize the impact of pipe breaks — such as valves, hangers and dampers — should be tested regularly to verify that they are functional.

I.73. Apart from the operating procedures associated with preventive actions, there should be procedures for the implementation of mitigatory actions and coping strategies in the event of pipe break impacts.

I.74. If a pipe break occurred and the plant has been returned to a safe state, a thorough inspection should be performed to reveal any damage that might have been caused by the different impacts of the break on its surroundings, including — depending on the importance of the rupture — the internal depressurization wave, high humidity, spray and high temperature in the room concerned.

INTERNAL FLOODING

I.75. Internal flooding at a nuclear power plant might be caused by leakages, pipe breaks, tank breaches or overflows, open valves, or the use of firefighting water. These can also be indirect effects of challenges from external hazards, such as seismic or external flooding events. The operating organization should ensure that the integrity of engineered structures and barriers designed to minimize the impact of internal flooding is maintained at all times.

I.76. Enhanced operational controls during construction, maintenance or inspection activities should be implemented to avoid increased flooding risks (e.g. controlling temporary water hoses during outage periods, limiting temporary storage that causes floor area reduction).

I.77. Operational controls should include inspections of water based systems for integrity before the systems are returned to service and should ensure that any temporarily modified drains, including temporary covers, have been restored to the pre-work conditions.

I.78. Measures for prevention of and protection and mitigation against internal flooding hazards should include level detection systems, engineered drainage routes, waterproofing measures to prevent flooding, and protection covers or embankments around structures and components to prevent water from spreading to other plant areas in an uncontrolled manner. Mitigation of internal flooding should be achieved in part by design choices with respect to the layout of the plant. Some flooding scenarios are naturally self-limiting (e.g. where the flood is limited to the contents of a single tank), whereas others might necessitate short term actions to be implemented by personnel.

I.79. General housekeeping rules will control debris in drain systems, but inspections and plant walkdowns should check the general good condition of drainage systems. Inspections or walkdowns should also ensure that flood doors are properly closed and secured, flood barriers are in place as designed, and flood mitigation measures are not compromised by a lack of sealing for drill holes or a lack of alternative barriers during maintenance.

I.80. For cases when evacuation or retention capacities cannot contain the flow of an internal flood, the operating organization should establish operating procedures for the detection and mitigation of internal flooding. The operating procedures should include instructions for the isolation of leaking systems and flooded rooms and the potential use of deployable pumping equipment to drain flood liquids. The personnel responding to flooding should be suitably trained in the application of these procedures (see para. 10.7).

HEAVY LOAD DROP

I.81. Analysis of the hazards associated with heavy load drop should be performed in accordance with the recommendations for heavy load drops provided in SSG-64 [4]. The prevention of structural collapses and falling objects from crane lifts is first and foremost ensured by conservative design. Nevertheless, falling object impacts from cranes and other lifting equipment should be considered a hazard. Non-crane-related load drops from heights might be related to mishandling of other heavy objects at height.

I.82. Hazard protection and mitigation measures should include using load following platforms, deploying deformable structures and installing protective dampers, if applicable, as well as load cells on hoists, fall zone controls, and limit switches on cranes and lifting equipment.

I.83. The operating organization should establish procedures for planning hoisting and lifting activities. Planning of these activities should include involvement of suitably qualified personnel, risk assessments, preplanned lifting routes, associated lifting equipment, additional supervision, defining of restrictions and interlocking of lifting routes, as applicable. Hazard management should ensure that at appropriate times after these activities, or periodically, the following items are consistent with design documents (e.g. the code or standards referenced in licensing documentation or in the design basis):

(a) Calculations for crane and lifting devices;
(b) Procedures used to implement inspections such as load testing, visual testing, dimensional testing, non-destructive testing of major load carrying welds, and inspection of critical areas for the lifting devices.

I.84. Communication protocols should be established between control room operators and personnel controlling and performing the lifts.

I.85. The operating organization should establish operating procedures to implement hazard management when there is a high risk of damage or multiple hazard impacts (e.g. fire, flooding) following a dropped load.

I.86. The operating organization should establish operating procedures for performing regular walkdowns and inspections of areas and structures where collapses might occur and objects might fall. Any such areas that are located outside plant buildings should be included for walkdowns or inspections when there is a high risk of the degradation of objects in the open air or from the impact of extreme winds. The operating organization should also establish procedures for performing regular walkdowns and inspections of areas and structures where a load might impact a structure, system or component during movement of the load via handling (i.e. along the horizontal and/or vertical axes).

I.87. The ageing management programme for the lifting equipment should ensure that the number of load cycles during the lifetime of the equipment is consistent with the result of the fatigue analysis.

I.88. Disabling of or changes to active protective measures (e.g. limiters, interlocks, trips) should only be allowed in accordance with preplanned procedures.

I.89. The scheduling of load movements and lifts in specified modes of plant operation (e.g. shutdown modes) should be considered as a preventive measure.

I.90. The integrity of engineered structures and barriers affected by a dropped load should be assessed.

ELECTROMAGNETIC INTERFERENCE

I.91. All potential sources of electromagnetic interference[12] and all items of sensitive equipment in the plant should be identified. Significant sources of electromagnetic interference can be eliminated by suitable design, construction and maintenance of instrumentation and control systems and of power supply systems and their components. Other potential sources of electromagnetic interference might include maintenance or construction activities and equipment such as portable arc welding equipment, portable radio communications or telephones brought into the plant, and ground penetrating radars used for ground surveys.

I.92. Within hazard management, the identification of electromagnetic interference hazards should take into account all potential sources of

[12] If the disturbance is in the high or radio frequency range, it is sometimes referred to as ‘radio frequency interference’.

electromagnetic interference during regular and specific maintenance periods or other plant activities.

I.93. The identification process for electromagnetic interference hazards should include the possible locations of permanent and temporary sources of electromagnetic interference, where possible, and should focus on sources close to sensitive equipment. The integrity of electromagnetic interference prevention or mitigation features should be checked after maintenance operations on electromagnetic interference sources or sensitive equipment (e.g. cable or equipment shielding, cable separation, earthing).

I.94. The identification process for electromagnetic interference hazards should contain checks for portable or temporary sources of electromagnetic interference. These checks should include the location and timing of maintenance and construction activities and exclusion zones or other administrative or operational controls to minimize an electromagnetic interference hazard, as well as the location of sensitive equipment (e.g. digital instrumentation and control systems, wireless equipment used at the plant, equipment used for maintenance and repair activities, measuring devices).

I.95. The personnel responsible for the activities where electromagnetic interference might be generated should have a role in hazard management for electromagnetic interference hazards. Communication between control room operators and the personnel performing the work might be necessary to terminate the source generating the interference and stop further effects on the plant.

RELEASE OF HAZARDOUS SUBSTANCES INSIDE THE PLANT

I.96. Releases of hazardous substances inside the plant and on the site are generally unlikely, limited in extent by design if they occur, and able to be avoided before they affect essential plant functions. However, the operating organization should consider the effects of hazardous substances on control room operators and the habitability of control rooms.

I.97. The operating organization should establish operating procedures to be followed where there are indications of a release of a hazardous substance inside the plant. Entry into these procedures is typically based on indications from a gas detection system or from direct reports from personnel. The objective of the operating procedures should be to limit exposure of the personnel during the event and ensure timely recovery of personnel after the release has dispersed.

I.98. In the case of an on-site release, operating procedures should include the isolation of damaged systems or storage tanks and of rooms with non-habitable atmospheres; preservation of habitable atmospheres in the main control rooms; and a process for partial evacuation of personnel involved in activities at the plant. The need to maintain personal protective equipment (e.g. breathing apparatus, protective clothing) on the site should be considered to allow control room operators to move to safe plant locations or perform safety related actions.

I.99. Protection and mitigation against the effects of an internal release of hazardous substances is largely ensured by passive design (e.g. redundancy of rooms or systems) and/or operating procedures. Operating procedures should include provisions to close dampers in the air inlet path of the ventilation system to the main control room, if necessary, and might also include other controls over ventilation flows.

Appendix II

TECHNICAL ASPECTS TO BE CONSIDERED IN HAZARD MANAGEMENT FOR PROTECTION AGAINST EXTERNAL HAZARDS

II.1. This appendix provides recommendations on elements of hazard management for specific external hazards in addition to the general recommendations for mitigating and coping with external hazards provided in Section 5.

SEISMIC HAZARDS

II.2. To ensure that seismic hazards are included in hazard management, the operating organization should consider and include specific actions derived from the results of the design and assessments performed as recommended in SSG-67 [5] and IAEA Safety Standards Series No. NS-G-2.13, Evaluation of Seismic Safety for Existing Nuclear Installations [30]. The plant personnel should have an understanding of the importance of specific seismic safety design and analysis results and components important to safety and their potential failure modes, interactions and challenges to redundancies.

II.3. The operating organization should develop an earthquake response plan for pre-event and post-event actions. These actions should be documented as procedures that describe short term and long term actions and include specific walkdowns for structures, systems and components to determine the status and functionality of hazard protection and mitigation features. Procedures for actions to be taken after hazardous conditions have passed should take into account challenges introduced by the seismic event, such as safe access to site areas and consequential hazards after an earthquake. The initiation of these procedures should be based on indications from the seismic monitoring system, information from off-site geological monitoring centres, or ground motion experienced by plant personnel. Insights on plant shutdown are provided in Ref. [31]. The indications from the seismic monitoring system should be calibrated to highly sensitive seismographs and strong motion accelerographs in regional and/or national monitoring networks as well as worldwide broadband seismograph networks, if necessary, as described in IAEA Safety Standards Series No. SSG-9 (Rev. 1), Seismic Hazards in Site Evaluation for Nuclear Installations [32].

II.4. The operating organization should maintain the seismic qualification of equipment required to perform safety functions during and/or after an earthquake. This could be achieved through implementation of an inspection programme to identify potential deviations, such as defects due to ageing or inadequate system configuration following maintenance or modification. Before an earthquake, the operating organization should observe the principles of good housekeeping to ensure that earthquake damage is not propagated or increased by temporary and/or loose items. This action should include securing items (through seismic restraints) that might cause damage to items important to safety during a seismic event. If a seismic event and a subsequent tsunami are defined, according to SSG-64 [4], as a credible combination of hazards, the operating organization should consider the response and ensure that the plant is adequately protected against the tsunami (e.g. flood protection gates in place).

II.5. If the plant is shut down after an earthquake, the operating organization should ensure long term safety during the shutdown. Examples of items to be considered are emergency diesel generator fuel supplies, off-site power supply, auxiliary power supply, control room habitability, and the restoration or possible repair of disabled or damaged items important to safety and of hazard protection and mitigation features. The operating organization should check the monitoring systems used to determine the expected type and level of damage to the plant and take appropriate actions for that damage level. If a subsequent tsunami is a credible combined hazard, the operating organization should include criteria for lead time (i.e. for the tsunami to reach the plant) and should take into account the severity of seismic damage to the plant in post-earthquake management.

II.6. If the plant is surrounded by mountains or hills, the operating organization should (a) consider implementing post-event monitoring for the condition of the slopes and for the sedimentation level of dams that were built to protect the plant from landslides and (b) prepare appropriate measures if unacceptable conditions are observed.

II.7. As appropriate, protocols for communication with off-site geological monitoring centres should be established for redundant seismic notifications. The data from regional and/or national monitoring networks, described in para. II.3, can be used for periodic updating of hazard management.

EXTERNAL FLOODS (STORM SURGES AND TSUNAMIS)

II.8. To ensure that external floods (i.e. storm surges and tsunamis) are included in hazard management, the operating organization should consider and include specific actions derived from the results of the design and the assessments performed on the basis of the recommendations provided in SSG-68 [6]. For example, in areas where tsunami hazards could occur, the tsunami flooding analysis might identify risks to structures, systems and components important to safety (e.g. the emergency generators and electrical distribution systems, the seawater system for the ultimate heat sink). The impact of tsunami backrush on the seawater system should also be taken into account. The impacts of tsunamis and storm surges are not limited to flooding, and in coastal areas the extensive and sudden movement of soft sediments or biological material also has the potential to affect the water intake system.

II.9. Since external floods by storm surges or tsunamis can be forecast to a certain extent, the operating organization should establish a warning system for external floods (including storm surges and tsunamis) and protocols for communication with national and local agencies that provide forecasts, where available. The hazard management for this hazard should take into consideration that the capability and available lead time in these forecasts might differ significantly (e.g. storm surge versus tsunami, far-field tsunami versus near-field tsunami). The hazard management should consider evacuation routes and safe refuges for personnel in the event of a tsunami.

II.10. If protocols for communication with national agencies are not available for tsunami warnings, the operating organization should consider the installation of a site area tsunami warning system.

II.11. The operating organization should establish and implement procedures that describe actions to be taken before, during and after the event and that correspond to the estimated height, arrival time and duration of the storm surge or the tsunami.

II.12. Before a flooding or storm surge event, monitoring of seawater levels should be initiated. The status of watertight doors, bulkhead openings and water intake structures should be checked. Actions should also be taken for any low water level conditions (e.g. stopping operation of the seawater pump). Site drainage systems and engineered water runoff systems should be checked, and their functionality should be ensured. Additional waterproofing measures should also be considered for vulnerable or sensitive areas.

II.13. Before the flooding event, the site should be inspected for loose equipment or structures that might become floating debris and cause structural loading if they were to impact structures or equipment during the event. If possible, these items should be removed from the site or secured so as to minimize hazard propagation during the flood, including restraining items that might become buoyant during an extreme flooding event and block drainage outlets or access routes.

II.14. Before the flooding event, operation and maintenance activities not related to the flooding hazard mitigation should be completed, and equipment and systems should be brought to a safe condition.

II.15. The operating organization should ensure personnel safety during the flooding event by clearly communicating the expected water levels and the potential for overtopping of dykes, dams or seawalls due to the combined effect of sea level variations and wind generated waves.

II.16. The operating organization should establish hazard mitigation measures such as removing debris or isolating damaged structures, systems and components to minimize flooding propagation and to avoid increasing damage to structures, systems and components important to safety.

II.17. For sites in cold climates, the operating organization should monitor regional ice conditions (e.g. coverage, thickness, duration) in seas and estuaries to minimize the impact on exposed structures (e.g. water intake) by flooding.

EXTERNAL FLOODS (FLOODING OF RIVERS AND STREAMS, AND FLOODS DUE TO EXTREME PRECIPITATION EVENTS)

II.18. To ensure that external floods (i.e. flooding of rivers and streams, and floods due to extreme precipitation events) are included in hazard management, the operating organization should consider and include specific actions derived from the results of the design and assessments performed on the basis of the recommendations provided in SSG-68 [6].

II.19. Since external floods by extreme precipitation or flooding of rivers are predictable to a varying extent, the operating organization should establish protocols and standards for communication with national and local agencies that predict such phenomena. The wide range in forecast capability for flooding of large rivers, flash flooding of small watersheds or local intense precipitation on the site should be considered.

II.20. The operating organization should establish and implement procedures that describe actions to be taken before, during and after the event and that correspond to the expected amount of precipitation or, in the case of river flood, the expected time of the different events.

II.21. Before the flood event, site water levels should be monitored continuously. The status of watertight doors, bulkhead openings and water intake structures should be checked, as appropriate. Also, the recommendation in para. II.12 for drain and waterproofing measures should be considered.

II.22. In the case of extreme precipitation, mitigation strategies should include ensuring that the site drainage systems are clear of debris and able to handle the expected water runoff. Where necessary, the operating organization should consider the use of mobile pumps to remove water.

II.23. The recommendations in paras II.14–II.16 for the activities of personnel should be considered.

II.24. The operating organization should ensure that there are adequate supplies of mobile pumps and other necessary flood mitigation equipment. Before the flooding event, the personnel should ensure that flood protection measures are installed and deployed as intended by the design.

II.25. The recommendation for management of slopes and of the sedimentation level of dams in para. II.6 should also be considered for extreme precipitation.

EXTREME WINDS

II.26. To ensure that extreme winds, including straight line winds, tornadoes and extratropical or tropical storms (i.e. cyclones, hurricanes and typhoons), are included in hazard management, the operating organization should consider and include specific actions derived from the results of the design and assessments performed on the basis of the recommendations in SSG-68 [6].

II.27. The operating organization should establish protocols and standards for communication with national and regional meteorological organizations to be properly warned of these hazards, including any rare meteorological phenomena.

II.28. The operating organization should regularly check the site meteorological systems, where installed, to ensure consistency with measurements by specialized meteorological organizations and to determine local weather conditions, if necessary. For example, a plant located in a narrow valley can be affected by a localized extreme wind that cannot be identified by wide-area weather forecasts. There are cases where this extreme wind can be aggravated by a change in the wind direction. This check can be done in the periodic updating of the hazard management (see Section 7).

II.29. Before any predicted extreme wind events, walkdowns and inspections of the site should be performed to identify and remove any loose debris and unsecured items or equipment stored around the plant site, especially metallic items. These activities should include reinforcing or removing any temporary scaffolding, securing any unstable equipment and conducting preparatory checks of emergency power systems.

II.30. Before any predicated extreme wind events, outdoor operation and maintenance activities not related to the mitigation of this external hazard should be completed and equipment and systems should be brought into a safe condition (e.g. tall cranes should be folded).

II.31. Depending on the severity of the extreme wind hazard, the operating organization should consider evacuating non-essential plant personnel.

II.32. Example checklists for use in the event of a tropical storm are the following:

(a) When a tropical storm is approaching the plant:
    — Identify the appropriate operating procedures for responding to the tropical storm, start frequent weather monitoring, and conduct patrolling and, if necessary, housekeeping outside the building in accordance with the plant's operations programme.
    — Confirm the availability and check the testing log of drainage pumps (if the hazard is combined with extreme precipitation) or other facilities in accordance with the surveillance programme.
    — Reconfirm the criteria for deciding to stop outdoor work in accordance with the work management of the maintenance programme (or, if necessary, management of the fuel management programme).
    — Establish internal and external communication systems in accordance with the plant's operations programme.[13]

[13] These actions might be taken as part of the emergency preparedness and response programme or as part of an independent comprehensive operational hazard management programme.

(b) When the expected alert area of extreme winds includes the plant:
  - — Assess whether all work can be continued in accordance with the work management of the maintenance programme (or, if necessary, management of the fuel management programme).
  - — Review the list of all work, preparation progress and incorporation of information from other plant programmes, including programmes for plant modification, operating experience feedback and nuclear security in accordance with the quality assurance programme (or relevant supporting functions).[13]
  - — Establish response teams including control room operators, on-site firefighters and nuclear security personnel in shift schedules in accordance with the plant's operations programme.[13]
  - — Take roll calls and confirm the safety of all personnel, including absent personnel, in accordance with the industrial safety programme.

(c) When a storm alert is actually issued for an area that includes the plant:
  - — Stop all work except essential work for safety and nuclear security, and notify as necessary external organizations (e.g. local government, emergency services, response organizations) in accordance with the plant's operations programme.[13]
  - — Instruct the evacuation of non-essential plant personnel in accordance with the industrial safety programme.
  - — Ensure the standby state of the drainage pump in accordance with the plant's operations programme (or, if necessary, the maintenance programme).
  - — Put structures, systems and components, including structures, systems and components for managing a severe accident, in a standby state in accordance with the accident management programme (or, if evaluated as necessary, in accordance with the safety assessment).

(d) When the alert is lifted:
  - — Instruct personnel to resume work after the necessary checks have been completed in accordance with the maintenance programme (or, if necessary, the fuel management programme).
  - — Release the response teams in accordance with the plant's operations programme.[13]

II.33. If the combination of extreme precipitation and extreme winds is defined as a credible combination of hazards (see also SSG-64 [4] for combinations of hazards), the operating organization should determine whether flood protection equipment should be put in place, depending on the anticipated severity of the combined hazards.

OTHER EXTREME METEOROLOGICAL CONDITIONS

II.34. To ensure that other extreme meteorological conditions, including extreme air temperature and humidity, extreme water temperature, snowpack, freezing precipitation, frost related phenomena and lightning, are included in hazard management, the operating organization should consider and include specific actions derived from the results of the design and assessments performed on the basis of the recommendations provided in SSG-68 [6]. This should include a full consideration of other effects of these extreme meteorological conditions, including the following:

(a) Low levels of sea water, which may be caused by extremes of air pressure;
(b) Sandstorms and dust storms;
(c) Low river or lake water levels from a drought caused by longer term extreme weather fluctuations.

II.35. The operating organization should establish protocols and standards for communication with national and regional meteorological organizations to be properly warned of any extreme meteorological conditions, including their possible duration. This information should be supplemented as necessary by use of the site's meteorological systems, where installed and available. For example, some plants can be notified of localized lightning strikes by a regional meteorological forecasting service that implements credible monitoring of atmospheric stability in a wide area.

II.36. In cases of extreme ambient air or water temperatures (hot or cold), analyses or testing of equipment or systems such as pumps, fans and cooling circuits (e.g. emergency cooling, cooling of essential services) should be performed to ensure that the equipment is working properly and to determine whether there is sufficient operating margin. Operating procedures should be developed and implemented to perform the necessary testing.

II.37. In cases of extreme ambient air temperatures, procedures should be developed and implemented to enhance area or equipment heating or cooling. Simple measures include opening or closing doors, using dampers and adding additional heating or cooling systems. The operating organization should ensure that these measures do not invalidate the plant's safety analysis for the areas or equipment. To ensure adequate energy supply to equipment that is important to safety, diesel fuel composition should be checked and, if necessary, adjusted.

II.38. If there is insufficient operating margin for equipment or systems, appropriate actions — such as cleaning heat exchangers or reducing pump flow — should be performed. In some extreme cases, safety margin might only be gained by reducing the reactor power.

II.39. Snow or large amounts of hail can block inlets or outlets of safety systems and safety features such as safety valves, blowout panels and intakes of heating, ventilation and air-conditioning systems. These should be cleared during and after the event. Installation of electric heaters should be considered.

II.40. The operating organization should establish procedures for removing snow at the site, if applicable. These procedures might include clearing of access routes, spraying of snow melting agents, operation of a snow melting system, as well as removal of snow from buildings to avoid the exceedance of design loads.

II.41. In cases of sandstorm or dust storm, the recommendation in para. II.53 for heating, ventilation and air-conditioning filter change should be considered. In addition, the recommendation in para. II.29 for securing equipment outside of buildings in an extreme wind event should be considered to prevent objects from becoming missiles.

II.42. At sites where frazil ice can occur, the temperature of the cooling water should be carefully monitored to ensure that the inlet of the cooling water circuit does not freeze. Freezing can be prevented by circulating warm water from the outlet circuit to the inlet.

II.43. The operating organization should ensure that the integrity of the plant's lightning protection system is maintained and the system is in an operational state.

II.44. When hail is predicted, the operating organization should remove or protect, as necessary, equipment located outdoors.

II.45. When an ice storm (i.e. a combination of high winds and supercooled rain; see also SSG-64 [4] for combinations of hazards) is predicted in the area of the external power grid, the operating organization should be prepared for a loss of external power caused by the rapid buildup of an ice layer on overhead line conductors.

II.46. When subsequent persistent precipitation is defined as a credible combination of hazards with extreme low temperatures, the operating organization should ensure that installed drains have been properly cleared to prevent compound effects, for example due to clogging by ice. Additionally, the operating organization should consider the potential effects of blocked drainage channels and how these could be mitigated.

II.47. If a reduction in the installed firefighting capability available to suppress potential internal fires is identified as a credible consequential effect of low temperature hazards with outside freezing conditions, then the operating organization should maintain the defence in depth by alternative firefighting measures.

VOLCANISM

II.48. Volcanic events can present significant hazards for nuclear power plants. Phenomena associated with volcanic events (volcanism) that might be accommodated by measures for design and operation are addressed in IAEA Safety Standards Series No. SSG-21, Volcanic Hazards in Site Evaluation for Nuclear Installations [33]. To ensure that volcanism is included in hazard management, the operating organization should consider and include specific actions derived from the results of the design and assessments performed on the basis of the recommendations provided in SSG-68 [6].

II.49. The operating organization should establish a warning system for volcanic hazards, if possible and applicable. Additionally, protocols and standards for communication with national or local agencies should be established to receive timely and comprehensive warning of volcanic activity and the potential for transport of volcanic ash and toxic gases.

II.50. The operating organization should develop specific procedures that guide control room operators in determining, on the basis of the warning and established reasonable criteria, such as proximity to the volcanic plume or ashes, whether a plant shutdown is necessary owing to volcanic activity.

II.51. Operating procedures should be developed and implemented for the inspection and removal of volcanic ash on or near structures, systems and components. Special considerations should include equipment (e.g. emergency diesel generators) affected by volcanic ash deposition impacting ventilation and structural loading.

II.52. Operating procedures should be developed and implemented to inspect and maintain the functions of the intake screens to prevent blockage of water intake structures and pumps, if applicable.

II.53. Operating procedures should be developed and implemented to monitor the differential pressures of heating, ventilation and air-conditioning filters and the air quality in the main control room. These procedures should include cleaning or replacing the filters as needed owing to the deposition of volcanic ash.

II.54. Operating procedures should be developed and implemented to inspect and clean electrical insulators for power cables, auxiliary power supply cables and switchyard connections that are important to safety, if applicable.

II.55. The operating organization should ensure that sufficient spare parts are available for equipment that might be impacted by volcanic ash deposition, if applicable. Special consideration should be given to the available quantities of ventilation filters.

II.56. The operating organization should consider the removal of volcanic ash from access routes to ensure the safe passage of personnel and emergency vehicles.

EXTERNAL FIRES

II.57. The recommendations provided in Appendix I, paras I.2–I.52, for internal fires are also valid for external fires. Additional specific recommendations for external fires are provided in paras II.58–II.66.

II.58. Protocols and standards should be established for communication with off-site agencies and organizations to enable them to notify the operating organization when activities involving combustible or explosive materials are performed. Because of the potential increase in the risk of external fires during these activities, these protocols and standards should require off-site organizations involved in these activities in relevant proximity to the site to notify the operating organization in sufficient time before the start of such activities and to provide information on the type, route and duration of the intended activities. This will allow the plant personnel to prepare for an accident that could involve combustible or explosive materials or that could impair structures, systems or components and impact the plant's external fire mitigation strategies.

II.59. Protocols and standards should be established for communication with off-site agencies and organizations to enable them to notify the operating organization when environmental or population conditions are such that external fires could occur (e.g. dry conditions, high winds, local festivals).

II.60. Communications from external organizations should include notifying the operating organization of the occurrence and the successful suppression of fires external to the site but in close proximity to the site area.

II.61. In the case of a notification of either the potential for or the occurrence of an external fire, the operating organization should notify the on-site firefighters and emergency response personnel of the hazard. This could result in the early deployment of on-site emergency response and firefighting equipment to a standby condition.

II.62. If there is an external fire with the potential to affect the site, the on-site firefighters should be on standby, which should include performing necessary equipment and personnel preparations.

II.63. Response to external fires will typically involve both on-site and off-site emergency workers. As such, the operating organization should conduct regularly scheduled training, drills and/or practical exercises with off-site organizations to ensure that coordination and response actions are understood by responsible emergency workers.

II.64. The operating organization should regularly inspect and, if necessary, maintain and repair all engineered structures and barriers (e.g. firebreaks, paved roads, earth mounds, dykes, walls, surrounding building structures) designed to prevent the spreading of external fires to the site.

II.65. To minimize the impact of external fires, the operating organization should regularly inspect and assess the engineered structures and barriers at the site or in close proximity to the site area. The scope of the inspection should include the effect of both permanent and temporary accumulations of combustible material and the presence of vehicles. If appropriate, this should lead to vegetation control or land clearing around buildings and site boundaries.

II.66. Owing to the potential for toxic gases and hazardous fumes from external fires, operating procedures should be established to ensure (a) proper use of air monitoring equipment and (b) isolation or realignment of various ventilation systems (e.g. the fan and filter unit for ensuring habitability of the main control room, the air-conditioning system for cooling the components, the air supply and exhaust system of emergency diesel generators). These procedures should be updated on a regular basis and in the case of relevant plant modifications.

EXTERNAL EXPLOSIONS

II.67. To ensure that external explosions (i.e. deflagrations and detonations) with or without fire and with or without secondary missiles are included in the hazard management, the operating organization should consider and include specific actions derived from the results of the design and assessments performed on the basis of the recommendations in SSG-68 [6].

II.68. In the case of a notification about potential off-site explosions or shockwaves, heat flux, smoke and heated gases, ground and other vibratory motions, or blast and missiles from explosions, the operating organization should notify the on-site firefighters and emergency response personnel about the hazard. This could result in the deployment of on-site emergency response and firefighting equipment to a standby condition. The recommendation in para. II.58 for communication with off-site organizations for external fires should also be considered for external explosions.

HAZARDOUS SUBSTANCES

II.69. To ensure that hazardous substances — including toxic, flammable, corrosive and asphyxiant chemicals and their mixtures in air and liquids — as well as radiological hazards from other on-site and collocated installations are included in the hazard management, the operating organization should consider and include specific actions derived from the results of the design and assessments performed on the basis of the recommendations in SSG-68 [6].

II.70. The operating organization should establish protocols and standards for communication with off-site agencies and organizations when significant movements of or activities with asphyxiants, toxic gases, and corrosive and radioactive liquids are planned to take place. Because the hazard increases during these times, off-site organizations within the external zone should notify the operating organization and emergency organizations when off-site activities (i.e. transport or movement) involving asphyxiants, toxic gases, and corrosive and radioactive liquids occur. This will allow the operating organization to prepare for an accident that could involve these substances and could impact the site's external hazard mitigation strategies. Regular and less significant movements might be excluded from these communication protocols but should be included in the plant's hazard mitigation strategies.

II.71. Operating procedures should be developed and implemented to properly monitor hazardous substances in the air, isolate the affected buildings or areas, ensure habitability for personnel, ensure cooling and operability of emergency diesel generators by ventilation realignments, and protect control room operators. These procedures should cover releases of hazardous materials from the plant and from other units on a multiple unit site, as well as any credible external sources of hazardous gaseous releases.

II.72. Operating procedures should be developed and implemented to ensure that the hazard will not propagate to unaffected buildings and areas by closing openings to unaffected buildings and areas, including windows and doors.

II.73. The need to maintain personal protective equipment (e.g. breathing apparatus, protective clothing) on the site should be considered in order to allow plant personnel and emergency workers to move to safe locations or to perform safety related actions.

II.74. The operating organization should consider sheltering or evacuating non-essential plant personnel and the potential need for external emergency response organizations to organize a safe evacuation from the site.

AIRCRAFT CRASHES

II.75. To ensure that accidental aircraft crashes are included in the hazard management, the operating organization should consider and include specific actions derived from the results of the design and assessments performed on the basis of the recommendations in SSG-68 [6].

II.76. While accidental aircraft crashes are protected against primarily by the design of the structure against the crash load, the operating organization should consider measures for mitigating the effects of a crash if it occurs and minimizing the likelihood of its occurrence. In this regard, as described in paras II.77–II.80, the operating organization should establish and maintain operating procedures and protocols for communication with national or regional air traffic control organizations for immediate and/or redundant notification of events.

II.77. The operating organization should review and apply the site specific requirements and report any violations of ‘no-fly zones’ to national or regional air traffic control organizations.

II.78. If the safety assessment identifies that aircraft crashes might necessitate the use of off-site firefighters and emergency response personnel, the operating organization should establish, maintain and implement communication protocols to ensure efficient response by these off-site personnel.

II.79. Response to an aircraft crash will typically involve both on-site and off-site emergency workers. As such, the operating organization should conduct regularly scheduled training, drills and/or practical exercises with off-site organizations to ensure that coordination and response actions are understood by all emergency workers.

II.80. The operating organization should develop a specific procedure for action and deployment of (a) mobile equipment to be used in deploying firefighting water and electrical power supply, which should be available on the site, and (b) on-site emergency response personnel when notified of this hazard. These procedures should include the prompt relocation of equipment and personnel from any potentially affected location to prevent an unacceptable loss of emergency response capability.

II.81. Since an aircraft crash on the site might result in the generation of hazardous substances, emergency workers should consider the recommendations provided in paras II.70–II.74, including the use of air monitoring equipment.

II.82. If practicable, the operating organization should develop a specific procedure for returning the plant to a safe state following an aircraft crash affecting the site.

II.83. If practicable, the operating organization should develop a specific procedure for evacuating, relocating or sheltering non-essential plant personnel and personnel necessary for emergency response (e.g. to a bunkered supplementary control room if the main control room is unprotected) when notified in sufficient lead time by the air traffic control organization of an aircraft crash potentially affecting the site.

ELECTROMAGNETIC INTERFERENCE, INCLUDING SOLAR STORMS

II.84. Large solar storms caused by solar flares and electromagnetic pulses can affect the electrical grid and the on-site electric equipment and instrumentation and control systems.[14] The operating organization should establish protocols for communication with the appropriate external organizations so that the operating organization can be informed of predictable solar flares by national agencies and as a result can take appropriate hazard mitigation measures for possible disturbances and notify external organizations of the plant's status. If necessary, the hazard mitigation measures should include the protection of telecommunication systems (e.g. by a combination of shielded phone devices and multiple satellite systems) and exercises in the use of those systems.

II.85. Large solar storms and electromagnetic pulses might impact the electrical grid, potentially resulting in a loss of external power supply to the plant. To prepare for a loss of power supply, a sufficient emergency fuel supply should be kept at the site.

II.86. As solar flares and electromagnetic pulses might also impact on-site electric equipment for the emergency power supply, such as transformers, the operating organization should perform proper monitoring, inspection and maintenance for such equipment.

II.87. The evolution of instrumentation and control in nuclear power plants includes more digital equipment and tends to increase the plant's vulnerability to electromagnetic interference. The operating organization should perform routine inspections and maintenance on cable shielding for such instrumentation and control systems.

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[14] Solar storms have a lower perturbation level than electromagnetic pulses but a wider area of effects. Solar storms will mainly have effects on long conductors such as pipelines and electrical lines (and connected transformers), whereas electromagnetic pulses can have effects on other equipment. The effects and the countermeasures for the two hazards might also be different.

BIOLOGICAL PHENOMENA

II.88. The operating organization should consider biological phenomena in hazard management, as appropriate. Biological phenomena encompass the following three types of biological hazard:

(a) Marine or water-borne biological hazards, such as jellyfish, seaweed, fish and mussels;
(b) Land based biological hazards, such as infestation from mice, rats and rabbits, and biological debris such as fallen leaves;
(c) Airborne biological hazards, such as swarms of insects or flocks of birds.

II.89. Biological hazards might include slower acting degradation, such as bacterial induced corrosion in supporting structures and pipework that leads to sudden or premature failure in components made from materials thought to be corrosion resistant. This degradation, however, should be addressed via maintenance, testing, surveillance and inspection programmes and ageing management programmes, including by the periodic reviews described in Section 7 of this Safety Guide. The recommendations in paras II.90–II.95 relate to the more immediate effects of biological hazards.

II.90. The cooling water and intake structures should be monitored continuously to ensure that any unusual accumulation of aquatic organisms is noticed in a timely manner and that measures can be taken to avoid clogging of intake structures or unacceptable degradation of cooling water quality. Protocols and standards should be established for communication with regional environmental, meteorological and waterway agencies to identify when biological hazards might be present or expected so that personnel can take timely actions to mitigate the hazard.

II.91. For water-borne biological hazards, the operating organization should consider the following:

(a) Use of chemical controls, where allowed by environmental regulations;
(b) Regular mechanical cleaning of cooling water and intake structures;
(c) Complete drainage and dry storage of cooling water structures and intake structures.

II.92. For infestations of animals, evidence of ingress or equipment damage should be sought during plant walkdowns. Where evidence is found, the operating organization should make arrangements to deter animals from entering buildings or provide specific protection against animal induced equipment damage.

II.93. For leaves and similar debris, routine inspections and walkdowns (including along the embankments of rivers, if applicable) should be performed to ensure that intake structures and drainage systems and equipment remain operational.

II.94. Swarms of insects might endanger heating, ventilation and air-conditioning equipment or emergency diesel generators by restricting airflow, thus limiting the operational capability of the equipment. Inspections and cleaning of the affected equipment should be performed when this hazard occurs.

II.95. Routine monitoring and dredging should be performed to ensure that the equipment for removing silt in water intakes remains operational.

HAZARDS FROM FLOATING OBJECTS AND HAZARDOUS LIQUID ON WATER INTAKES AND COMPONENTS OF THE ULTIMATE HEAT SINK

II.96. The operating organization should establish and implement communication and response protocols with regional or national maritime authorities, as appropriate, to be forewarned of ships adrift in heavy weather and of the possibility of ice masses or large floating debris colliding with the plant, so as to provide the operating organization with sufficient time to prepare for the mitigation of any associated hazards.

II.97. For prevention of collisions by ships, large pieces of debris or large amounts of water-borne debris, the operating organization should establish and implement notification and response protocols with navigation and coastguard authorities.

II.98. If applicable, operating procedures should be developed and implemented to prepare and use an alternative ultimate heat sink to accommodate a potential loss of normal cooling or ultimate heat sink systems.

II.99. To prevent damage to plant equipment and facilitate recovery actions, operating procedures should be developed and implemented for the deployment of (a) floating booms or curtains to intercept oil spills or (b) surface skimmers to keep any oil at a safe distance from water intake structures.

II.100. Operating procedures should be developed and implemented for the identification of potential debris accumulation in water intake structures and for the subsequent cleaning.

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