IAEA SAFETY STANDARDS

for protecting people and the environment

SPESS Step 8 – Soliciting comments by Member States

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

DS 503

DRAFT SAFETY GUIDE

Revision of NS-G-2.1 and enhanced scope

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FOREWORD

[To be added]

EDITORIAL NOTE

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

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

The English version of the text is the authoritative version.

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1. INTRODUCTION

BACKGROUND

1.1. 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 the protection against internal and external hazards in the operation of nuclear power plants. This Guide provides new or updated recommendations on 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 and improvements in the protection measures against such hazards identified in various internal and external 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 include IAEA Safety Standards Series Nos. SSG-64, Protection against Internal Hazards in the Design of Nuclear Power Plants (under publication) [4], DS498, External Events Excluding Earthquakes in the Design of Nuclear Installations [5] and DS490, Seismic Design of Nuclear Installations [6].

1.6. This Safety Guide supersedes IAEA Safety Standards Series No. NS-G-2.1, Fire Safety in the Operation of Nuclear Power Plants[1].

1.7. Operating experience gained from incidents and accidents in nuclear power plants around the world has continued to demonstrate that fire continues to be an important risk contributor in many States. A number of other hazards also have to be taken into account in the design and operation of nuclear power plants. The risk due to fires at a specific plant site, as with many other hazards, is dependent on plant-specific factors in design and operation.

OBJECTIVE

1.8. The purpose of this Safety Guide is to provide recommendations on the operational management of nuclear power plants in relation to preparing for, prevention, protection, mitigation and coping with internal and external hazards as well as with the impacts of those hazards, to meet the safety requirements established in SSR-2/2 (Rev. 1) [1].

1.9. The recommendations in this Safety Guide are aimed primarily at operating organizations of nuclear power plants and regulatory bodies. They 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.

SCOPE

1.10. This Safety Guide applies to water cooled nuclear power plants designed and operated in accordance with the requirements provided in IAEA SSR-2/1 (Rev. 1) [2] and SSR-2/2 (Rev. 1) [1], and with the recommendations complemented by IAEA SSG-64 [4], DS498 [5] and DS490 [6]. For reactors cooled by other media, including gas cooled

[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).

reactors, or reactors based on innovative design concepts, some of the recommendations in this Safety Guide might not be fully applicable, as application of these recommendations depends on the particular technology and the risks associated with internal and external hazards.

1.11. This Safety Guide provides detailed recommendations for the internal fire hazard which is common in most nuclear power plants. As detailed application for other hazards will be site specific, this Safety Guide also provides the high-level recommendations applicable to a broad range of hazards, reactor types, and different operating phases.

1.12. 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].

1.13. This Safety Guide does not specifically address conventional aspects of protection of the safety of operating personnel, or the protection of property, except where this could affect the safety of the nuclear power plant.

1.14. This guide does not address societal or pathological hazards (e.g. pandemic) that do not directly impact the safety of the nuclear power plant.

1.15. This Safety Guide excludes postulated internal and external initiating events induced by deliberate human acts of malicious intent. Prevention and mitigation of malicious acts that could lead to such events (either by on-site personnel or by third parties) are outside the scope of this Safety Guide, and guidance on this issue is provided in the IAEA Nuclear Security Series.

1.16. In the protection of nuclear power plants against internal and external hazards, safety measures and security measures should be designed and applied in an integrated manner, and as far as possible in a complementary manner, so that safety measures do not compromise security, and vice versa. This Safety Guide includes interfaces between nuclear safety and nuclear security. In dealing with these interfaces, it should be borne in mind that nuclear safety and nuclear security are equally important, and measures to be taken should be mutually acceptable in both areas.

STRUCTURE

1.17. Section 2 provides general recommendation on protection against hazards in the operation of nuclear power plants. Section 3 focuses on the organization and responsibilities of the hazard management. Sections 4 and 5 provide recommendations for ensuring safety for internal and external hazards, respectively. Section 6 provides recommendations on the combination of internal and external hazards. Section 7 provides recommendations on updating the hazard management. Section 8 provides recommendations on material control and housekeeping on the hazard management. Section 9 provides recommendations on the maintenance and testing of equipment for hazard prevention, protection, mitigation and coping. Section 10 provides recommendations on training of personnel for hazards. Appendices I and II provide detailed information on technical aspects to be considered in internal hazards and external hazards, respectively.

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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 include natural or human induced events that originate outside the site boundary and outside the activities that are under the control of the operating organization, for which the operating organization has very little or no control. Such events are not connected to the operation of the site or conduct of an activity on the site, but could have an adverse effect on the safety of the site or activity. In this Safety Guide, the word "hazard" or "hazards" refers to both internal and external hazards, and to the combination of these hazards unless where specifically noted. Examples of internal and external hazards are provided in paras 5.16 and 5.17 of SSR-2/1 (Rev. 1) [2].

2.2. The term 'hazard management' is used to refer to a set of operational processes and measures for prevention, protection and mitigation of hazards, and strategies for coping with the impact of these hazards to ensure safe operation of nuclear power plants. The hazard prevention, protection and mitigation features include safety systems and safety features, that were not originally installed or designed as safety systems or measures.

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) on the management system [1] states:

> **"The operating organization shall establish, implement, assess and continually improve an integrated management system."**

2.5. The integrated management system should integrate hazard management. Hazard management should aim at reducing the potential for common cause failure and thus reducing threats to safety. The consideration for the management processes and management programmes are presented in Section 3.

2.6. Requirement 11 of SSR-2/2 (Rev. 1) [1] states:

> **"The operating organization shall establish and implement a programme to manage modifications."**

The operating organization should maintain and update, as necessary, all features for prevention, protection and mitigation of hazards as part of the programme for managing modifications. Recommendations for hazard management and its review regarding modifications are provided in Sections 3 and 7.

2.7. 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 method and the development of hazard management through the periodic safety review are provided in section 7.

2.8. Requirement 18 of SSR-2/2 (Rev. 1) [1] states:

> **"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:

> **"The operating organization shall establish, and shall periodically review and as necessary revise, an accident management programme."**

2.9. Hazard management and decision making in hazard management should be harmonized with the emergency plan and the accident management programme, to ensure coping with events arising from internal or external hazards and mitigation of the consequences of these events in case of a nuclear or radiological emergency. Requirements for emergency preparedness and response are established in IAEA GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency [7]. Recommendations on accident management and preparedness for a nuclear or radiological emergency are provided in IAEA Safety Standards Series Nos SSG-54, Accident Management Programmes in Nuclear Power Plants [8] and GS-G-2.1, Arrangements for a Nuclear or Radiological Emergency [9], 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 [10]. While these IAEA Safety Standards provide recommendations on the radiation-related hazards in a severe accident or radiological emergency management, this Safety Guide covers all the other means that assist the operating organization in coping with hazards with minimal consequences.

2.10. Requirement 22 of SSR-2/2 (Rev. 1) [1] states:

> **"The operating organization shall make arrangements for ensuring fire safety."**
> (Requirement 22 of SSR-2/2 (Rev. 1) [1])
> "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

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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) Inspection, maintenance and testing 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."
(para. 5.21 of SSR-2/2 (Rev. 1) [1]).

The recommendations for hazard management specifically relating to fire safety are presented in Appendix I. Special attention should be paid for the application of the principle of defence in depth for fire safety (see para. 2.24.).

2.11. 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." (Requirement 23 of SSR-2/2 (Rev.1) [1]).

"The non-radiation-related safety programme [footnote omitted] 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" (para. 5.26. of SSR-2/2 (Rev. 1) [1]).

The hazard management should be implemented by the personnel involved in activities at the plant. The measures for hazard management should be considered as part of the measures implemented to ensure the industrial safety of the personnel.

2.12. 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].

2.13. Requirement 28 of SSR-2/2 (Rev. 1) [1] states:

> **"The operating organization shall develop and implement programmes to maintain a high standard of material conditions, housekeeping and cleanliness in all working areas."** (Requirement 28 of SSR-2/2 (Rev. 1) [1])
>
> "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." (para. 7.10 of SSR-2/2 (Rev. 1) [1])

The operating organization should monitor the potential impact of material conditions and manage housekeeping on the occurrence or progression of hazards and their consequences.

2.14. Requirement 31 of SSR-2/2 (Rev. 1) [1] states:

> **"The operating organization shall ensure that effective programmes for maintenance, testing, surveillance and inspection are established and implemented."**

The operating organization should identify the potential hazards that might arise during maintenance, testing, surveillance and inspection activities. These hazards should be taken into account when developing the programme for hazard management. Hazard management should be related to the programme for maintenance, testing, surveillance and inspection.

2.15. 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 the potential hazards that might arise during outages, including low power and shutdown modes. Hazard management should take into account the dynamic changes in plant conditions during outages and factors such as availability of safety features during shutdown, protection zones (e.g. containment vessel) and increased resources (e.g. workers, combustibles, scaffoldings, vehicles).

2.16. 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 implemented and maintained during decommissioning, taking into account any changes in the assessed hazards.

2.17. Hazard management should include all consequences of hazards occurring at different reactor units or at different nuclear power plants at the same site for the case of multiple plants very near sites or on the same site operated by differing operating organizations.

2.18. Hazards can induce initiating event that might cause failures of equipment or means that are necessary for preventing harmful effects, and that might adversely affect, directly or indirectly, the barriers and might lead to releases of radioactive material and associated hazardous material.

2.19. 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, hazards do not trigger a more severe plant state, leading into accident conditions. For example, hazard management could help ensure that multiple failure of safety systems caused by a single fire event be avoided.

2.20. Inspections should be implemented for equipment and features that cope with (and, if possible, detect) hazards, detect signs that might lead to the occurrence of an internal hazard, or are needed for the implementation of corrective actions to ensure protection against a hazard. Where necessary, additional inspections should be in place for coping with hazards. Hazards should be taken into account in the planning and conduct of inspections.

2.21. Operational provisions for hazard management should be consistent with the recommendations provided in the following safety guides:

- IAEA Safety Standards Series No. NS-G-2.3, Modifications to Nuclear Power Plants [11][2];
- IAEA Safety Standards Series No. NS-G-2.4, The Operating Organization for Nuclear Power Plants [12];

[2] NS-G-2.3 provides specific recommendations for the management programme for plant modifications, including processes relevant to the hazard management measures such as specific safety consideration for industrial hazards and temporary emergency procedures during modifications.

- IAEA Safety Standards Series No. NS-G-2.6, Maintenance, Surveillance and In-Service Inspection in Nuclear Power Plants [13][3];
- IAEA Safety Standards Series No. NS-G-2.8, Recruitment, Qualification and Training of Personnel for Nuclear Power Plants [14];
- IAEA Safety Standards Series No. NS-G-2.14, Conduct of Operations at Nuclear Power Plants [15][4];
- IAEA Safety Standards Series No. SSG-25, Periodic Safety Review for Nuclear Power Plants [16];
- IAEA Safety Standards Series No. SSG-54, Accident Management Programmes in Nuclear Power Plants [8].

APPLICATION OF DEFENCE IN DEPTH FOR HAZARD MANAGEMENT

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

2.23. The operating organization should consider following an approach for defence in depth applicable during operation by a combination of maintaining engineered features presented in IAEA SSR-2/1 (Rev. 1) [2] and implementing procedural measures presented in IAEA SSR-2/2 (Rev. 1) [1] to protect the plant from hazards. The engineered features primarily complement the implementation of defence in depth and the procedural measures against hazards provide additional assurance to engineered features, by monitoring, warning, alerting, post event management and assessment of unanticipated plant failures.

2.24. In accordance with Requirement 22 of IAEA SSR-2/2 (Rev. 1) [1] and Requirement 7 of IAEA SSR-2/1 (Rev. 1) [2] on the application of defence in depth, the operating

[3] NS-G-2.6 provides specific recommendations for the management programme for maintenance, testing, surveillance and inspections, including processes relevant to hazard management such as work control and administrative procedures for fire hazard control; surveillance programmes for equipment for mitigation and coping with hazards; and management for limiting the risk of fire, flooding, earthquake, missiles and release of hazardous substances at storage facilities.

[4] NS-G-2.14 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, formal communication systems with plant organizations 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.

organization should verify defence in depth for internal fire hazards in-line with corresponding operational limits and conditions (See Appendix A.1.).

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3. RESPONSIBILITIES OF THE OPERATING ORGANIZATION 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 thereof, 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 from hazards or a credible combination of these hazards. The operating organization should utilize 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 GSR Part 2 [17], defined roles and responsibilities of the personnel involved in the establishment, implementation, and administration of the hazard management are required to be identified, documented and maintained up to date in the management system. The arrangements for the delegation of authority for these responsibilities should also be documented, implemented and maintained up to date. Further recommendations on the management system for nuclear installations are provided in GS-G-3.5 [18].

3.4. The operating organization should identify the organizational structures, processes, specific responsibilities, level of authority, and interfaces of personnel involved in hazard management within the organization and with external organizations, if necessary. These external organizations should be identified taking 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 forecasted. The operating organization should identify and establish staffing levels and capabilities of the personnel, before an event, to mitigate and cope with hazards.

3.6. The operating organization should establish documented plans and protocols for preventing hazards and for mitigating and coping with the impacts of hazards and their consequences and should ensure that the plant personnel is trained and qualified in these plans and protocols. In these plans and protocols, the operating organization should include a combination of personnel from the various site sections or departments such as engineering, operations, maintenance, technical support and emergency response. The operating organization should also ensure that an adequate number of qualified staff are

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available at all times to operate the plant safely in operational states and abnormal conditions in case of hazards and induced effects [15].

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).

HAZARD MANAGEMENT

3.8. Hazard management is required to be integrated with the nuclear and radiation safety programme (See Requirement 23 of IAEA SSR-2/2 (Rev.1) [1]).

3.9. The set of hazard management measures should be structured, documented and associated to management programmes and processes 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 NS-G-2.4 [12]) and recommendations on the development of operational procedures for hazard management measures are provided in NS-G-2.14 [15].

3.10. The incorporation of measures for hazards into the plant management programmes and processes can be based on the graded approach (see GSR Part 4 (Rev. 1) [19]). Factors to be taken into consideration include the degree of safety significance of the site specific hazards, 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 resource optimization.

3.11. The hazard management and the decision making for hazard management should be harmonized with the guidance and actions included emergency preparedness and response programme and accident management programme of the plant for mitigating and coping with the event progress from hazards to a nuclear or radiological emergency. Requirements and recommendations on the preparedness for a nuclear or radiological emergency are established in GSR Part 7 [7] and GS-G-2.1 [9], and recommendations on accident management are provided in SSG-54 [8].

3.12. The hazard management should consider and include procedures for:

- The prevention of avoidable hazards that can affect nuclear safety;
- Detection of hazards;
- Hazard prevention, protection and mitigation features and procedures for unavoidable hazards or credible combinations thereof that can affect nuclear safety;
- Mitigation measures in the event that hazards or credible combinations of hazards exceed protection levels;

– Strategies for coping with hazard impacts: the methods implemented to deal with an adverse situation for an indefinite period of time.

3.13. The hazard management should be maintained applicable and relevant to the plant throughout the entire plant lifetime. The hazard management should be reviewed periodically and updated as necessary to take into account any changes in the plant state, including plant modifications, changes in the site characteristics, results of research and development, new scientific knowledge, lessons learned, best practices from industry operating experience. The results of this periodic review should be used to identify and implement in a timely manner any practicable design modifications and changes in the arrangements for hazard management, including organizational arrangements, strategies and measures.

3.14. The operating procedures for hazard management should set out the roles of the operating personnel in relation to the roles of any external organizations (e.g. law enforcement organizations, fire brigade).

3.15. Strategies for coping with hazard impact should be developed taking into account the civil infrastructure such as electric power, watering, communications, transportation, and the collections of buildings that make up communities around the plant, as a part of the hazard management. These strategies should take into account the infrastructure of the region around a site, such as roads, railways, electrical grid interfaces, presence of sources of water and proximity to water ways, regional population centres and local industries, with special consideration to the infrastructure that might present hazard challenges to the site.

3.16. The 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. The operating organization should establish separate or integrated procedures for different types of hazard. These procedures should provide clear instructions to the operating personnel on actions to be implemented if precursors and indications of hazards, and potential precursors to events resulting from hazards occur.

3.18. The emergency arrangements of the operating and external organizations should ensure that special consideration is given to cases where there is a risk of radioactive releases as consequence of an event initiated by a hazard.

3.19. The hazard management should include provisions to ensure the safety of those personnel responsible for implementing the measures for hazard prevention, protection and mitigation and the strategies for coping with hazard impact. These provisions should also

cover the radiation protection of the personnel of the operating organization and of external organizations operating on the plant (e.g. fire fighters). Recommendations for occupational protection of workers in a nuclear or radiological emergency is provided in GSG-7 [10].

DECISION-MAKING FOR HAZARD MANAGEMENT

3.20. In accordance with the requirements established in GSR Part 2 [17], the plant management is required to develop and maintain an understanding of the safety significance of the nuclear power plant.

3.21. The plant management should have an understanding of how nuclear safety features and features for hazard prevention, protection and mitigation could be affected by hazards, taking into consideration the safety assessment and graded approach [19]. This includes an understanding of hazard management measures to increase the plant's resilience.

3.22. The plant management should have an understanding of the security features of the nuclear power plant, as these that might also be affected by the impact of hazards or the necessary mitigation measures.

3.23. In accordance with the requirements established in GSR Part 2 [17], the operating organization is required to ensure that the plant management can activate established programmes, processes and procedures to protect the plant against potential hazards, and to be prepared to implement hazard mitigation measures and/or strategies for coping with hazard impact[5]. The following aspects should be taken into consideration, as appropriate:

- 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 potential hazards that could be used as input for the decision-making process and to activate hazard management measures such as firefighting or transporting equipment (e.g. drainage pumps) which might be stored off-site. Sections 4 and 5 of this Safety Guide provide further examples of such equipment.
- Nuclear security aspects: Hazard management should be developed in consultation with physical protection experts and should include procedures

[5] 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 for a tropical storm is presented in Appendix II.32.

to inform security personnel of any modifications to the physical protection features and of the occurrence of any hazard to ensure the necessary operations are followed for evacuation, hazard mitigation measures and strategies for coping with hazard impact. Further guidance on nuclear security is provided in Refs. [20–23].

– Multi-unit plant sites: For multiple reactor units co-located at the same site or at adjacent sites, either 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 hazards with an increased predictability. The operating organizations should ensure appropriate cooperation with other operating organizations at the same site or at adjacent sites.

3.24. When a hazardous event has occurred or hazardous conditions have been forecasted, a decision-making process should be initiated by the operating organization to ensure the following:

– A timely assessment that the response criteria for specific hazards are met;
– The performance of time-sensitive actions and confirmation of these actions to manage the risk imposed by the hazard;
– Identification of any support needed (e.g. from internal organizations, from external organizations, emergency support equipment, specialized personnel);
– Maintaining the fundamental safety functions required for the appropriate plant operating mode.
– Identification of alternative actions if a specific action cannot be performed.

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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 GSR Part 4 [19], an initial hazard analysis is required to form part of the basic design phase. Internal hazards can be prevented and mitigated to a large extent by the design and construction of engineered features. This initial hazard analysis should be supplemented to take into account the operational procedures for preventing, mitigating and coping with internal hazards. Site-specific aspects (especially for multi-unit or multi-source sites) are also required to be considered in the plant design against internal hazards (see Requirement 17 of SSR-2/1 (Rev. 1) [2]) and the operation of the plant (see Requirement 23 of SSR-2/2 (Rev. 1) [1]).

4.3. The hazard analysis and the operating procedures for preventing, mitigating and coping with 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 credible internal hazards on SSCs. This hazard analysis will inform the hazard management (see Section 3). Further recommendations on protection against internal hazards in the design of nuclear power plants are given in SSG-64 [41].

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

4.6. Enhanced administrative and procedural controls over material housekeeping and operations should be put into place (see Section 8) as part of the hazard management for periods of increased risk (for example, during outages or during the implementation of modifications), in order to ensure that the hazard prevention, protection and mitigation measures are not reduced.

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

4.8. Hazard management should include the following elements that should be adapted to the specific hazard characteristics, as appropriate:

- Identification of response criteria commensurate with the internal hazard and the potential consequences;
- Identification of appropriate warning or monitoring systems and equipment for the hazard;
- Identification and assessment of the nuclear safety challenges and functional challenges caused by the hazard, e.g. specific equipment that may need protection from the hazard;
- Development and implementation of procedures for maintenance and inspection of equipment needed to cope with and mitigate the hazard;
- Development and implementation of communication standards and protocols with external organizations;
- Training of personnel to ensure development of necessary skills for implementing mitigation measures.

RECOMMENDATIONS FOR SPECIFIC INTERNAL HAZARDS

4.9. Recommendations for design related aspects of internal hazards are provided in IAEA SSG-64 [4]. For all credible internal hazards, the general recommendations given in paras 4.1–4.8 are applicable.

4.10. Appendix I provides detailed recommendations for hazard management of the following commonly considered internal hazards:

- Internal fires;
- Internal explosions;
- Internal missiles;
- Pipe breaks (pipe whip and jet effect and flooding);
- Internal flooding;
- Heavy load drop;
- Electromagnetic interference;
- Release of hazardous substances inside the plant;
- Other site specific or design specific internal hazard as appropriate.

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

5.1. The hazard management for protection against external hazards should be based on identification of site-specific external hazards and plant vulnerabilities. These are identified, for example, in connection with site evaluation, plant design, periodic safety reviews, evaluation of operating experience, and if applicable, the probabilistic risk assessment for external hazards. Levels of hazards more severe than those considered in the design should also be considered in the hazard management as an interface with accident management, based on the evaluation of the impact of these hazards. IAEA DS498 [5] and DS490 [6] provide general recommendations on the design aspects of external hazards including hazard analysis.

5.2. Based on the external hazard impacts included in the hazard management, potential measures for hazard protection and mitigation should be identified for each hazard that can increase the viability of a strategy for coping with external hazards. See para. 7.1 on the periodic monitoring of external hazards.

5.3. Before activating the established processes and procedures for protection against potential hazards, the operating organization should put in place processes and procedures to ensure that meteorological forecasts are monitored and that appropriate actions are taken in due time when weather-related hazardous conditions are forecasted (e.g., coastal flooding, severe storms, tornadoes). For predictable or partially predictable hazards[6], the operating organization should undertake the decision making process described in para. 3.24. to ensure that the site is prepared in a timely manner.

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

[6] The basis of a valid forecast or prediction is formed by facts that are collected using formalized methods and forecast technologies to create data. Resulting predictions are available from national and regional organizations which are specialized in their production and provision. On-site monitoring can support the information. On this basis decisions then can be made with a certain probability.

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5.5. Hazard management should include strategies for the deployment of operating personnel and equipment, and the procedural implementation of these strategies.

5.6. Enhanced administrative and procedural controls over material housekeeping and operations should be put into place (see Section 8) for periods of increased risk (for example, during outages or during the implementation of modifications), in order to ensure that the hazard protection and mitigation measures are not reduced.

5.7. Hazard management for external hazards should include the following elements that should be adapted to the specific hazard characteristics and especially the predictability of the hazard:

- Identification of a realistic predictability or warning time for the hazard, and response criteria commensurate with the external hazards identified and the potential consequences;
- Identification of appropriate warning or monitoring systems and equipment for the hazard;
- Identification and assessment of the nuclear safety challenges and the functional risk caused by the hazard (e.g. specific equipment that might need to be protected against the hazard);
- 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 certain natural external hazards;
- Development and implementation of procedures for maintenance and inspection of equipment needed to cope with and mitigate the hazard;
- Development and implementation of a plant strategy for responding to events without warning (e.g. response actions for a specific hazard such as debris removal following a seismic event);
- Development and implementation of communication protocols with external organizations;
- Training of personnel to ensure development of the necessary skills for implementing 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, as appropriate. The operating organization should define and take into account all additional hazards that can be generated by an original hazard, and also define credible combinations of hazards (see Section 6).

5.9. The operating organization should take actions to prevent or mitigate the propagation of hazard effects throughout the entire site before (for a forecasted event) or during the event for an external hazard that impacts a vulnerable or sensitive part of the site. This includes ensuring 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. Adverse working conditions of the operating personnel because of the hazard should be taken into consideration when developing the operating procedures for hazard management. The safety of the operating personnel should be taken into account, particularly during an event.

5.10. There is a wide range in the capability to forecast external hazards. Some external hazards such as seismic events, aircraft crashes, and industrial accidents are generally unpredictable and the hazard management should assume that there will be no warning. For other hazards, there can be a forecast capability depending on the phenomena and the forecast lead time. For example, external flood on certain large river systems can be forecasted with considerable accuracy days to weeks in advance. Coastal flooding due to tropical and extratropical storms can be forecasted hours to days in advance. Conditions favourable for formation of severe storms and tornadoes can be forecasted using the distribution of atmospheric pressure hours in advance, but there can be very little warning for the precise location and intensity of such phenomena. The hazard management should consider the forecast capability for each credible external hazard and develop measures 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. for high winds, tornadoes), and the removal of items that could prevent proper site drainage (e.g. in the event of heavy rainfall, storm surges). Communication and notification protocols should ensure that the operating personnel are aware of the likelihood of a specific hazard.

5.11. Depending on the predictability of the external hazard and the communications 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 hazards and the available time, the operating organization should consider evacuating all non-essential plant personnel within correctly estimated evacuation time.

5.13. After the cancellation of a national or regional hazard warning, the operating organization should take actions to return the plant to operational states and ensure that if

any personnel were temporarily assigned to coping with hazards return to their normal duties in a controlled manner.

RECOMMENDATIONS FOR SPECIFIC EXTERNAL HAZARDS

5.14. For all external hazards, the recommendations provided in sections 5.1– 5.13 are applicable. Appendix II provides more detailed recommendations that should be incorporated into hazard management for protection against external hazards for the following common external hazards:

- Seismic hazards;
- External floods (storm surges and tsunamis);
- External floods (flooding of rivers and streams, and floods due to extreme precipitation events);
- Extreme winds;
- Other extreme meteorological conditions;
- Volcanism;
- External fires;
- External explosions;
- Toxic, radioactive, flammable, corrosive or asphyxiant chemicals, and their air and liquid mixtures;
- Aircraft crash;
- Electromagnetic interferences, including solar storms;
- Biological phenomena;
- Hazards by floating objects and hazardous liquid on water intakes and components of the ultimate heat sink;
- Other site specific or design specific external hazards as appropriate.

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6. COMBINATION OF HAZARDS

6.1. Hazard management should take into consideration the effects of combined hazards and mitigation strategies against these combined hazards. Some examples of the considerations for combinations of hazards in hazard management are given in Appendices I and II.

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

6.3. The hazard management for the hazard combinations should be performance-based and define a desired outcome and clear, measurable criteria to determine whether that outcome has been reached [4]. This Safety Guide provides recommendations on developing performance-based measures for hazard combinations in hazard management, but does not prescribe steps for each specific combination, nor on how to combine hazards.

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. The hazard management should include information on how combinations of hazards could alter the overall situation of the plant and how this is handled. Combinations of hazards can alter hazard mitigation measures and strategies for coping with hazard impact, operating procedures, special hazard mitigation equipment, the internal and external organizations that need to be involved, communication protocols, and post-accident management considering any deterioration or damage to hazard mitigation features.

6.5. The operating organization should review the applicability of operating procedures and deployment of the necessary mitigation equipment for each individual hazard taking into account the potential effects of the combinations of hazards applicable at the site. Operating procedures for separate hazards could 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 may be stored in an area that is affected by another hazard and then the equipment cannot be used for its original purpose.

6.6. If a combined hazard event occurs that has not been anticipated in the safety assessment, then the precautionary conservative decision-making principles should apply (see para. 3.24). For reactors that are in operation at the time of occurrence of the combined hazard, shutdown or power reduction should be considered by the operating organization. The operating personnel should then follow the site accident management programme in accordance with the requirements in IAEA SSR-2/2 (Rev. 1) [1], and the recommendations SSG-54 [8]. For example, anticipation and consideration for a combination of hazards

categorized as unrelated (independent) events [4] might not be recommended unless the combination of events is shown to have a sufficient probability [5]. The operating organization should maintain situational awareness when responding to those unrelated events and use judgment to ensure the fundamental safety functions based on 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 combinations of hazards, i.e., of a hazard causing the initiation of other hazards (consequential or correlated hazards).

6.8. Communication protocols with internal or external organizations might need to take hazard combinations into account. These communication protocols should be developed considering the effects of hazard combinations based on specific plant conditions. For example, different external organizations might need to be involved for certain hazards. If there are multiple hazards, there might be more organizations involved in the response with different roles and responsibilities. These roles and responsibilities could be overlapping or even be conflicting with each other.

6.9. The performance-based approach for hazard combinations should be developed using a systematic process to categorize hazard combinations and should then screen the hazard mitigation measures and strategies for coping with hazard impact on the basis of the significance of effects on the plant and the frequency of occurrence. IAEA 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 coping strategies for hazards that rise from consequent events should receive more special attention, than hazards that rise from independent events.

6.10. For all defined hazard combinations, the operating organization should consider the duration of the consequential effects of each hazard in hazard management, rather than the duration of the hazard itself. For example, a seismic event might last just a few 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 mitigation measures of the rainfall event could be different than when the plant is operating in normal conditions. The plant personnel response for these cases can be based not only on the response criteria for both individual hazards, but on specific management measures that relate to a combination of these hazards.

7. PERIODIC UPDATING OF HAZARD MANAGEMENT

7.1. The understanding of the potential effects of hazards on the plant and the importance of maintaining the fundamental safety functions should be continuously sustained while periodically updating the hazard management throughout the lifetime of the plant. Continuous periodic monitoring of external hazards should be considered, especially at the early stage of the lifetime of the plant. Further recommendations on management of plant operations are provided in NS-G-2.4 [12].

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

- If additional hazards are identified;
- If there is a reassessment of the severity of hazards in the specific stage of plant life;
- As part of a re-licensing application
- As part of a Periodic Safety Review [16];
- If the severity of a hazard or the plant vulnerability to a hazard was not previously recognized;
- 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 cliff edge effects or challenges to multiple layers of defence in depth that were not previously identified or addressed.

An update of hazard management should include harmonization with other programmes at the plant site, such as monitoring programmes or emergency preparedness programmes.

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

7.4. The operating organization should also take into consideration operating experience from hazard events that have already occurred at the installation or elsewhere. Further recommendations on implementing an operating experience programme to improve plant equipment, procedures and training are provided in SSG-50 [24].

7.5. The operating organization should identify and implement design and procedural recommendations based on initial and periodic safety assessments, where conditions of low margin to external hazard mitigation and cliff edge effects can be identified.

7.6. The operating organization should consider and address, in the periodic updating of hazard management, SSCs important for hazard prevention, protection and mitigation

including portable emergency equipment and passive design features. The effect of ageing of SSCs should also be taken into account.

7.7. Procedures, trainings, drills, and exercises for hazard coping and mitigation strategies and measures 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 the contact information of external organizations, changes in regional population sizes and the proximity of these populations to the site, electrical grid interfaces, changes in transportation routes, changes in local industries, and hydrological and geological changes.

7.9. The potential effects from changes in hazards should be identified and updated based on the periodic site hazard reassessment and periodic safety assessment results (as needed). Additional considerations might be needed for multiple units (e.g. extreme wind could cause the loss of off-site power if the switchyard is shared between units or if neighbouring units have changed their operating state affected by different hazards).

7.10. Modifications in the nuclear power plant design and/or operation during its lifetime (with regard to both equipment and organization) should be reflected in hazard management. Hazard management should be reviewed and updated following any plant modification, periodically, and as specified by the regulatory body.

7.11. If proposed solutions to potential hazard impacts are not implemented, the justification for not implementing the solutions should be reviewed and documented. The technical justification should describe any compensatory features provided to maintain an acceptable level of safety, where applicable.

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8. CONTROL OF MATERIALS AND HOUSEKEEPING IN HAZARD MANAGEMENT

8.1. The management and control of materials and housekeeping on a routine basis can impact the progression of hazards and their consequences.

8.2. The hazard management should include specific plant walkdown procedures to be conducted periodically, before and after an event. The results of these walkdowns should be properly documented. These walkdowns should ensure that the SSCs needed for prevention, protection and mitigation of events due to hazards and for coping with effects from hazards are in place and maintained operable in a reliable manner. Some examples of walkdowns are the following:

- Ensuring that culverts are kept clean immediately before a predicted major external flooding as they can have a significant impact on the ability of the site drainage systems to dewater the site.
- Ensuring loose materials (especially heavy objects) are cleared away or tied down as they can create potential airborne missiles if the hazard occurs.

Some of these actions are of particular importance when an external hazard (such as extreme winds or flooding) is forecasted, 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 forecasted (Requirement 28 of SSR-2/2 (Rev. 1) [1]). Further examples of actions that need to be taken, and checked during these 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. INSPECTION, MAINTENANCE, AND TESTING OF HAZARD PROTECTION AND MITIGATION MEASURES

9.1. In accordance with Requirement 31 in IAEA SSR-2/2 (Rev. 1) [1], the operating organization is required to establish and implement a comprehensive programme to perform maintenance, testing and inspections of hazard protection and mitigation measures identified in the hazard analysis. Further recommendations on such programmes are provided in IAEA Safety Standards Series No. NS-G-2.6, Maintenance, Testing, Surveillance and In-Service Inspection in Nuclear Power Plants [13].

9.2. The maintenance of design features for hazard prevention, protection and mitigation should be included in surveillance programmes to ensure protection against and mitigation of internal and external hazards by conservative design. The operating organization should perform regularly scheduled inspections and maintenance activities to preserve the integrity and functional availability of all engineered structures and barriers designed to mitigate hazards.

9.3. The operating organization should develop and maintain a list of hazard protection measures for the site and should implement inspection, maintenance and testing activities to ensure their availability. The operating organization should set the exploitation conditions of these hazard protection measures in their operability requirements. If the protection measures are associated with the safety analysis, the operability specifications should be set in accordance with the results or assumptions of the analysis. If these operability specifications cannot be met, alternative measures should be specified and implemented to reduce the risk (see para. 9.5), and the time allowed to complete these alternative measures should be indicated.

9.4. The inspection, maintenance and testing for the site should include general hazard protection measures and protection measures for specific hazards. Hazard protection measures that should be inspected, maintained, and tested include the following:

- Hazard detection and alarm systems;
- Communication systems for use in the occurrence of a hazard;
- Emergency lighting systems;
- On-site mobile equipment and features for mitigating hazard effects such as emergency vehicles, bilge pumps, mobile diesel generators;
- Engineered structures, fittings and barriers such as fire doors, watertight doors, dampers and penetrations;
- Access routes and escape routes for hazard response personnel;
- Respirators and protective clothing for radiological applications.

9.5. Inspection, maintenance or testing 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 adequate level of safety is continuously maintained during the off-line states of those original measures by inspection, maintenance or testing. Some examples of alternative measures are the following:

- Sustaining fire barriers, monitoring and fire-fighting equipment (e.g. placing watchmen during fire sensor repairs, securing water lines or fire extinguishers while fire water systems are partially isolated);
- Ensuring that flood doors or flooding hazard mitigation measures are not compromised by the lack of sealing for the drill holes or by the lack of alternative barriers during the maintenance;
- Deploying alternative mobile equipment for spray water for the reactor or for spent fuel pit and electrical power supply;
- Deploying emergency response personnel.

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

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

9.7. The operating organization should consider additional combustibles as fire loads during the maintenance periods (See Appendix I).

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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 IAEA SSR-2/2 (Rev. 1) [1]. Recommendations on training of personnel are provided in IAEA Safety Standards Series No. NS-G-2.8, Qualification and Training of Personnel for Nuclear Power Plants [14].

10.2. Specialized training on 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; differing training courses can be provided to different individuals or groups.

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

10.4. Training should be sufficient to ensure that individuals understand the significance of their duties and the consequences of errors arising from misconceptions or lack of diligence, and that individuals 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 reflect the current plant configuration and hazards.

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

- Hazard safety principles at the plant;
- General awareness of specific hazards (see para. 10.7);
- Roles and responsibilities of the personnel for hazard management before, during and after hazard events;
- Recognition of audible and visual alarm signals including fire alarms, tsunami warnings, and other alarms as applicable to the site;
- Exits and emergency evacuation routes in the event of an internal or external hazard;
- The need to delay or discontinue certain plant activities in case specific external hazards are predicted such as extreme ambient temperatures, flooding, or extreme wind; including the means of reporting hazards and actions to be taken to make work safe;

- The different types of portable or resilience equipment provided and their use in mitigating hazard effects in the initial stage. This might include fire-fighting 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 the duties for prevention, protection or mitigation on hazards should cover the following topics, which are common for all hazards:

- 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;
- 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;
- The significance of planned design changes and plant modifications with respect to hazards without affecting equipment qualification and safety classification, including both direct and indirect impacts on nuclear 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;
- Familiarization with the physical location of SSCs, preferably through a plant walkdown;
- Familiarization with the physical location of hazard prevention, protection and mitigation features of the plant;
- Detailed knowledge of the design and testing requirements of hardware for hazard protection and knowledge of specific design objectives for those features in each area of the plant, as specified in the safety assessment or similar documentation to ensure that the personnel responsible for the review of planned design changes and plant modifications are sufficiently knowledgeable to recognize issues that may have implications on hazard prevention, protection and mitigation features.

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10.7. The training for personnel who initiate or authorize relevant work activities and for personnel who may be assigned the duties for prevention, protection or mitigation on different hazards should cover specific topics, as follows:

For fire hazards:

- How to control combustibles and to ensure that area limitations on fire loadings are met;
- Awareness of potential ignition sources, and controls over them – for example using hot work procedures;
- Passive fire protection including the importance of fire doors, barriers and penetrations, as well as relevant working practices;
- Fire detection, alarm and reporting means and actions to be taken;
- Recognition of audible and visual fire alarm signals;
- Means for access and escape as well as emergency evacuation routes in the event of fire;
- The designated assembly point for evacuation.
- Preventing adverse effects from consequential flooding;
- Different types of fire extinguishing equipment provided and their use in extinguishing fires in the initial (incipient) stage;
- Fire safety policy at the plant;
- Awareness of specific fire hazards (including combined hazards), including limitations on area fire loading and, where necessary, associated radiological concerns;
- Significance of the control of combustible materials and ignition sources and its potential impact on the permissible fire loading in an area;
- The hazards associated with activities such as cutting and welding that could produce a potential ignition source;
- The stipulations of the work permit system, specific situations in which a fire watch is necessary, and the risk of introducing potential ignition sources into fire areas containing components identified as important to safety;
- Instructions on work implementation and general fire safety training so that the personnel can readily recognize various fire hazards in the plant and can understand the implications of introducing combustible materials or ignition sources into safety related areas;
- The significance of controlling risk during the hot work and the instructions for the preferable alternative fire prevention, protection and mitigation features to sustain protective barriers (e.g. watchmen during fire sensor

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repairs, securing water lines or fire extinguishers while fire water systems are partially isolated.

For floods external to the buildings:

– The role of watertight doors and the need for them to be kept closed by default to protect against external flooding;

For seismic events:

– The significance of field housekeeping to avoid extraneous debris or loose items;
– Information on drills and exercises including prompt decision making, notification, communication with external organization, shutdown, work control, evacuation, and other mitigating actions in line with the on-site emergency plan (see paras 3.11. and 10.10);

For internal floodings:

– The role of water barriers, drainage systems, the significance of the floor area control against temporary storage, and the result and the assumption of the flooding analysis;
– The ability to respond (detect and isolate) to leaks in diverse locations within evaluated time.

For extreme wind and other meteorological hazards:

– Awareness of the hazards associated with loose items and the potential that they might become wind-borne missiles, as well as the need of restriction for vehicle parking and equipment storage;
– The work control and evacuation scheme according to the meteorological alert level;
– Awareness of the potential collapse of temporary platforms and scaffolds and the need to adequately secure them.

10.8. Because certain activities might lead to additional risks involving internal or external hazards, training for personnel who initiate or authorize these activities should be provided. Some examples of these types of additional risk are provided in para. 10.9.

10.9. Personnel who initiate or authorize work activities involving the movement or transport of radioactive material should be trained to ensure they are aware of the following:

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- 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 movement operations.
- The method by which the site receives and communicates information on forecasts for events such as extreme wind, flooding and other hazards that could affect the ability of the operating personnel to perform the fuel or waste movement safely.
- Actions to take if a seismic event occurs during movement or transport of a fuel or waste to verify that the integrity of the transport package has not been compromised and that the receiving facility has not been damaged and is still able to accept the fuel or waste.

EXERCISES AND DRILLS

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

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

10.12. Results from exercises and drills should be systematically evaluated 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 Requirement 22 in SSR-2/1 (Rev. 1) [2] 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, the staff of 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.

I.1. INTERNAL FIRES

DEFENCE IN DEPTH

I.2. To ensure adequate fire safety in a nuclear power plant in operation, 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:

- Preventing fires from starting;
- Detecting and extinguishing quickly those fires which do start, thus limiting the damage;
- Preventing the spread of those fires which have not been extinguished, thus minimizing their effects on essential plant functions.

I.3. By satisfying these three objectives, it should be ensured that:

- The probability of a fire occurring is reduced to as low as reasonably practicable;
- SSCs are adequately protected to ensure that the consequences of a single fire will not prevent those systems from performing their required function, taking into account the effects of the worst single failure.

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 fire protection measures; quality assurance; and emergency arrangements. These aspects are addressed in the following paragraphs.

FIRE SAFETY MANAGEMENT

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

I.6. Plant personnel engaging in activities relating to fire safety should 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 appreciation of the potential consequences of errors.

I.7. Personnel should be encouraged to adopt a rigorous approach to their firefighting activities and responsibilities and a questioning attitude in the performance of their tasks, to foster continual improvement.

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 established and corrective actions should be taken to prevent a recurrence. The potential implications for fire prevention and protection of operating experience from fires at other plants should be considered. Communication should be maintained, and information exchanged between plants (and with the regulatory body) on safety related aspects of fire safety.

FIRE PREVENTION AND PROTECTION

I.9. Procedures should be established for the purpose of ensuring that amounts of combustible materials (the fire load) and the numbers of ignition sources be minimized 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 fire loads, and the reliability of the features in place for detecting, extinguishing and mitigating the effects of fires, including established fire barriers.

ORGANIZATION AND RESPONSIBILITIES

I.11. The operational organization should establish an on-site group with the specific responsibility for ensuring the continued effectiveness of the fire safety arrangements. Responsibility for coordinating fire safety activities should be assigned to an individual personnel position, 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 the fire prevention and protection.

FIRE HAZARD ANALYSIS

I.13. A comprehensive fire hazard analysis should be performed for the plant in order to do the following:

- Demonstrate the adequacy of fire protection means (both passive and active) in place to protect areas identified as important to safety for all plant operational states;
- Identify any specific areas where levels of fire protection are inadequate and where corrective measures are necessary;
- Provide a technical justification from the recommended practices (see IAEA SSG-64 [4]) for which no corrective measures are taken.

The fire hazard analysis should be updated regularly over the lifetime of the plant.

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

I.15. The technical justification from recommended practice (IAEA SSG-64 [4]) that is identified when the fire hazard analysis is updated should include a discussion of the plant modifications that would be necessary to follow accepted practice and the reasons why it is not reasonably practicable to implement such modifications. The technical justification should also describe compensatory features provided to maintain an acceptable level of safety, where applicable.

IMPACTS OF PLANT MODIFICATIONS ON FIRE SAFETY

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 fire hazard analysis update:

- Modifications to the fire protection features;
- Modifications to the protected items important to safety or systems that could adversely affect the performance of the fire protection features;
- Any other modification that could adversely affect the performance of the fire protection features, including modifications fire load per floor area.

I.17. Operating licences issued to nuclear power plants usually include a requirement for approved, written procedures for controlling modifications to SSCs. All proposed plant modifications should be scrutinized for their potential effect on area fire loading and fire

protection features, since a modification involving non-safety-related SSCs could conceivably change a fire load per floor area 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 protection. Modifications should not be commenced until the review has been completed.

I.19. The personnel assigned the responsibility for performing such reviews for issues of fire safety should be suitably qualified to evaluate the potential effect of any modification on fire safety and 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 on the authority of a work permit issued by a person who is competent in and knowledgeable of the implications for fire safety. It also should be ensured that physical protection personnel are notified of the modifications to the characteristics of the nuclear facility'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 item(s) important to safety or hazard prevention, protection and mitigation features, and appropriate temporary arrangements should be made to maintain adequate protection against fires. 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 system, the plant as modified should be commissioned and 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

I.23. Administrative procedures should be established and implemented for effective control of combustible materials throughout the plant. The written procedures should establish controls for delivery, storage, handling, transport and use of combustible solids, liquids and gases. Consideration should be given to the prevention of fire related explosions within or adjacent to areas identified as important to safety. For areas identified as important to safety, the procedures should establish controls for combustible materials associated with normal plant operations and those which may be introduced in activities related 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 identified as important to safety. Such materials should be removed as soon as the activity is completed (or at regular intervals) or will be temporarily stored in approved containers or storage areas.

I.25. The total fire load due to combustible materials in each area identified as important to safety should be maintained as low as reasonably practicable, with account taken of the fire resistance rating of the compartment boundaries. Records should be maintained that document the estimated or calculated existing fire load as well as the maximum permissible fire load in each fire area.

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

I.27. Administrative controls should be established and implemented to ensure that areas important to safety are inspected periodically in order to evaluate the general fire loading and plant housekeeping conditions, and to ensure that means of access and escape routes for manual fire-fighting 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 identified as important to safety during maintenance and modification activities. These procedures should cover combustible solids, liquids and gases, their containment and their storage locations in relation to other hazardous material 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 potential temporary fire loads should determine whether the proposed work activity is permissible and should specify any additional fire protection measures that are needed (such as the provision of portable fire extinguishers or the use of a fire watch officer, as appropriate).

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 identified as important to safety. The procedures should be accordance with national practice and should provide controls for solids and liquids.

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

- The use of combustible materials (such as wooden scaffolding) should be restricted. Where wooden materials are permitted, they should be chemically treated or coated so as to be fire retardant.
- The storage of combustible materials such as charcoal filters and dry unused ion exchange resins should be restricted; large stocks of such materials should be placed in a designated storage area with appropriate fire rated compartmentation and fire protection measures provided.
- The storage of combustible materials such as papers and protective clothing should be restricted; large stocks of such materials should be placed in designated storage areas with appropriate fire rated compartment barriers and fire protection measures provided.
- The storage of all other combustible materials should be prohibited.

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

- The amounts of flammable or combustible liquids introduced into fire areas 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, as appropriate.
- Approved containers or dispensers should be used whenever possible for the transport and use of flammable or combustible liquids. Openings in containers should be fitted with spring loaded closures. Transport of flammable or combustible liquids in open containers should be avoided.
- If it is necessary to store small amounts of flammable or combustible liquids within a working area, cabinets of an approved design for flammable liquids should be used.
- All containers of flammable or combustible liquids should be clearly and prominently labelled to indicate their contents.
- Stores of large quantities of flammable or combustible liquids should be located and protected such that they should 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 as appropriate.
- Warning signs should be placed at storage areas for flammable or combustible liquids.

I.32. Administrative procedures should be established and implemented to control the delivery, storage, handling, transport and use of flammable gases through-out the plant. The procedures should be established in accordance with national practice and should be implemented to ensure that the following:

- 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;
- Where a supply of flammable gas is needed in-side a building for permanent use, it is supplied from cylinders or a bulk storage area safely located out-side the building in a dedicated storage area such that a fire affecting the storage area would not com-promise safety.

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

- Restrict personnel smoking to designated safe areas and to prohibit personnel from smoking in all other areas;
- Prohibit the use of open flames for testing heat or smoke sensing devices (such as fire detectors) or for leak testing purposes;
- Prohibit the use of portable heaters, cooking appliances and other such devices in areas identified as important to safety;
- Limit the use of temporary wiring.

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. by means of either the work permit system or a special system for hot work permits. 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 fire watch (if stipulated) and access for firefighting. All personnel concerned with the preparation, issuing and use of permits for hot work should be instructed in the proper use of the 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 the work should be trained in the use of any fire safety features provided.

I.35. In areas containing items important to safety, work which involves the use of a potential ignition source or which might create ignition sources (“hot work”) 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 hot work permit identifies the need for a fire watch, the following procedures should be followed:

- 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.
- While the work is in progress the fire watch should perform no other duties.
- Suitable dedicated fire-fighting equipment should be readily available and means should be provided by which additional assistance can be readily obtained, if necessary. Adequate access and escape routes for fire fighters 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 to permanently control ignition sources.

INSPECTION, MAINTENANCE AND TESTING OF FIRE PROTECTION MEANS

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

- Passive fire rated compartment barriers and structural elements of buildings, including the seals of barrier penetrations;
- Fire barrier elements with active functions such as fire doors, fire dampers;
- Separating or protective elements such as fire-retardant coatings and qualified cable wraps; fire detection and alarm systems including fire detectors, flammable gas detectors and their electrical support systems;
- Water based fire extinguishing systems;

- A fire water supply system including a water source, a supply and distribution pipe, sectional and isolation valves, and fire pump assemblies;
- Gaseous and dry powder fire extinguishing systems;
- Portable fire extinguishers;
- Other manual firefighting equipment including emergency vehicles;
- Smoke and heat removal systems and air pressurization systems;
- Emergency lighting systems;
- Communication systems for use in fire incidents;
- Respirators and protective clothing for radiological applications;
- Access and escape routes for firefighting personnel;
- Emergency procedures.

MANUAL FIREFIGHTING CAPABILITY

I.43. A fire-fighting strategy (if necessary, as preplanned) should be developed for each area of the plant identified as important to safety (including those areas, which present a fire exposure risk to areas 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 fire fighters to use safe and effective fire-fighting techniques in each fire area. 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 fire-fighting strategy developed for each fire area of the plant should cover the following:

- Access and escape routes for fire fighters;
- Locations of structures, systems or components identified as important to safety;
- Fire loadings;
- Particular fire hazards, including the possibly reduced capability for fire-fighting due to external hazards;
- Special radiological, toxic, high voltage and high -pressure hazards, including the potential for explosions;
- Fire protection features provided (both passive and active);
- Restrictions on the use of specific fire extinguishing media because of concerns about nuclear criticality or other particular concerns, and the alternative extinguishing media to be used;
- Locations of heat and/or smoke sensitive items important to safety;
- Location of fixed and portable extinguishing equipment;
- Water supplies for manual firefighting;

- Communication systems (not affecting items important to safety) for use by fire-fighting personnel;
- Physical protection features and notification procedures for plant physical protection personnel;
- Consideration for inadmissible effects of firefighting (e.g. the use of water or other extinguishing media) for SSCs important to safety (e.g. measuring converters on the bottom level of the reactor annulus), when the subsequent internal flooding is defined as credible combination of hazards.

I.44. Plant documentation should provide a clear description of the manual fire-fighting capability provided for those areas of the plant identified as important to safety. The manual fire-fighting capability may be provided by a suitably trained and equipped on-site fire brigade, by a qualified off-site service or by a co-ordinated 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 plant and the off-site firefighter. Designated operating personnel in each shift should be assigned the responsibility to coordinate and liaise with the off-site firefighters and to establish 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 a qualified on-site fire brigade.

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

I.47. If an on-site fire brigade is established to provide a manual fire-fighting capability, the fire brigade’s 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 fire brigade should be physically capable of performing fire-fighting duties and should attend a formal programme of fire-fighting training prior to assignment to the plant fire brigade. Regular training (routine classroom training, fire-fighting practice and fire drills) should be provided for all on-site fire brigade members. Special training should be provided for fire brigade leaders to ensure that they are competent to assess the potential safety consequences of a fire and advice control room personnel.

I.49. If manual firefighting represents the primary means of fire protection, it should be ensured, as far as possible, that the necessary actions in the event of fire can be carried out safely in terms of radiological protection.

FIRE RELATED TRAINING OF PLANT PERSONNEL

I.50. All plant personnel and contractors' 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 staff should establish minimum initial qualifications for all personnel involved in fire safety functions and activities which 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 SAFEY

I.52. Fire protection features (including preventive features) are not generally classified as hazard prevention, protection and mitigation features and thus they might not be subject to the rigorous qualification requirements and the associated quality assurance programme applied to hazard prevention, protection and mitigation features. However, fire has the potential to fail multiple systems and thus to pose a threat to safety, and therefore the active and passive fire protection measures should be considered as important to safety. An appropriate level of quality assurance should therefore be applied to fire protection features.

I.2. INTERNAL EXPLOSIONS

I.53. The operating organization should consider various explosion sources when preventing, detecting, and mitigating internal explosions. Potential sources of internal explosions might be related to the use or the generation of explosive gases. There is also a potential for dust or oil mist explosions although these are judged less likely. Additionally, events leading to an energy release similar to an explosion might also come from high energy arc flashes in electrical equipment. Explosion events might also occur in conjunction with other hazards, such as fire.

I.54. The potential formation of an explosive atmosphere should be avoided or limited using non-flammable liquids or processes (such as water-based solvents, operating contamination monitors with inert gases, 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 controls over materials and operations during times of increased explosion risks.

I.56. Active and passive protection systems (such as gas detectors, blast doors, blowout panels, room and area ventilation systems) should be subject to the inspection, maintenance and testing programmes identified in the hazard management.

I.57. Operating procedures (e.g. area ventilation procedures, area or system isolation procedures) should play a role in preventing explosion events and in any post-explosion event.

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 be established in accordance with national practice and should be implemented to ensure the following:

- Containers 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;
- 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.59. Control of ignition sources is the main prevention 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 will be controlled by means of formal written procedures, i.e. by means of either the work permit system discussed earlier or a special system for hot work permits. Since flammable gases might have the potential to create explosive mixtures which can cause an explosion with ignition sources being present. The recommendations provided for internal fire are also applicable.

I.60. In areas containing items important to safety, work which involves the use of a potential ignition or explosion source or which 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 the areas containing such components.

I.61. The operating organization should control and/or limit personnel access in areas where explosion hazards could occur such as main and auxiliary transformer areas.

I.3. INTERNAL MISSILES

I.62. Potential missile sources are present at all nuclear power plants. The operating organization efforts should focus on ensuring 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 is mitigated before it affects 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 and include the following:

- Regular plant area walkdowns to detect potential missile hazards;
- Observation of personnel interacting with potential missile sources;
- Rotating machinery inspections including means to limit the rotational speed and monitoring and surveillance measures;
- Regular turbine blade inspections for turbine blade degradation;
- Inspection of storage areas of high-pressure gas bottles and the integrity of the gas bottles themselves;
- In the areas where SSCs are located, inspection of the pressure vessels and of high energy valves to detect possible flaws (the presence and good tightening of all bolts fastening the cap of the valves on their bodies should be checked).

I.64. The operating organization should control and/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 potential missile events at the site. These indications of a potential missile event 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 operating personnel, or video monitoring of plant areas.

I.66. Operating procedures after missile events should include actions such as plant walkdowns to determine the missile impact on the integrity and functionality of SSCs important to safety.

I.67. Much of the protection provided against the effects of missile hazards is from basic layout decisions in design, and by passive hazard protection such as engineered barriers. The passive

features should be subject to the inspection, maintenance, and testing programmes identified in the hazard management, and the plant surveillance programmes (see section 9).

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

I.4. PIPE BREAKS (PIPE WHIP AND JET EFFECT AND FLOODING)

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 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 walk downs of plant areas should be performed to confirm that the plant conditions correspond to those stated in the design, including identification of items that hinder or make ineffective leak detection devices, proper closure of compartment doors, and proper installation of protective covers. These periodic walkdowns should also include inspections to identify general pipe and piping component degradations, and steam and water leaks and inspections of engineered barrier integrity, pipe whip restraints, pipe hangars, 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 if necessary, thereby preventing pipe failures. Engineered movable structures designed to minimize the impact of pipe breaks like valves, hangers, and dampers should be tested regularly to prove they are functional.

I.73. Apart from the operating procedures associated with preventive actions, there should be procedures related to the implementation of mitigating actions in the event of pipe break impacts that should include implementation of coping strategies.

I.74. If a pipe break occurred and the plant 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 in its surrounding, including the internal de-pressurization wave, high humidity, spray, and high temperature in the room concerned.

I.5. INTERNAL FLOODING

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

I.76. Enhanced operational controls during construction, maintenance or inspection activities should be implemented during times of increased flooding risks (e.g. temporary water hoses during outage period, temporary storage which causes floor area reduction).

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

I.78. Prevention, protection and mitigation measures against internal flooding hazards should include level detection systems, engineered drainage routes, water proofing measures to prevent flooding, and protection covers or embankments around significant structures and components to prevent water 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 flood scenarios are naturally self-limiting (for example where the flood is limited to the contents of a single tank), whereas others might necessitate short-term actions to be implemented by the operating personnel.

I.79. General housekeeping rules control debris in drain systems, but inspections and plant walk downs should check the general condition of drainage systems (verification that these systems can provide the adequate draining flowrate). Inspections or walk downs 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 the lack of sealing for the drill holes, or lack of alternative barriers during the maintenance.

I.80. 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 required to respond to the flooding should be suitably trained to the application of these procedures (See para. 10.7).

I.6. 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 paras 4.170–4.183 in SSG-64 [4]. The prevention of structural collapses and falling objects from crane lifts is first and foremost realized by a conservative design. Nevertheless, falling objects impacts from cranes and other lifting equipment should be considered as a potential 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 load following platforms, deployable deformable structures and protective dampers if applicable, as well as load cells on hoists, fall zone controls, and crane and lifting equipment limit switches.

I.83. The operating organization should establish procedures for planning hoisting and lifting activities. Planning of these activities should include risk assessments, pre-planned lifting routes, associated lifting equipment, additional supervision, defining of restrictions, and interlocking of lifting routes, as applicable. The hazard management should ensure that in appropriate timings after these activities, or periodically, the following items are consistent with design documents such as the code or standards referenced in licensing or in the design basis:

(i) Calculations for crane and lifting devices, or

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

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

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 and objects might fall. Those areas which 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 impacts of extreme winds.

I.87. The ageing management programme for the lifting equipment should be established to ensure that the number of load cycles during the lifetime of 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 pre-planned procedures.

I.89. The scheduling of load movements and lifts in specified modes of plant operation (such as shut-down modes) should be considered as a preventive and mitigative measure.

I.90. The integrity of engineered structures and barriers affected by drop of loads should be assessed.

I.7. ELECTROMAGNETIC INTERFERENCE

I.91. All potential sources of electromagnetic interference (EMI)[7] 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 also of power supply systems and their components. Other potential sources might include maintenance or construction equipment and activities such as portable arc welding equipment, portable radio communications or telephones brought into the nuclear plant, and ground penetrating radars used for ground surveys.

I.92. Within hazard management, identification of potential electromagnetic interference hazards should account for all potential sources during normal or special maintenance periods or other plant activities.

I.93. The identification process for electromagnetic interference hazards should include the potential location of permanent and temporary sources of electromagnetic interference, where possible, and focus on sources close to sensitive equipment.

I.94. The identification process for electromagnetic interference hazards should contain controls for portable or temporary electromagnetic interference sources. These controls should

[7] If the disturbance is in the high or radio frequency ranges, it is sometimes referred to as radio frequency interference (RFI), but in the context of this document, electromagnetic interference is used as the generic term.

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, including wireless equipment used at the plant, equipment used maintenance and repair activities, and measuring devices.

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

I.8. RELEASE OF HAZARDOUS SUBSTANCES INSIDE THE PLANT

I.96. Releases of hazardous substances inside the plant are generally viewed as unlikely, limited in extent if they occur, and can be avoided before they affect essential plant functions. However, the operating organization should consider the effects of hazardous substances on control room operators performing important actions, and in particular on the habitability of the main control room.

I.97. The operating organization should establish operating procedures that characterize actions following indications of a hazardous substance release inside the plant. Entry into these procedures is typically based upon indications from a gas detection system, or from direct reports from the operating personnel. The objective of the operating procedures should be to limit exposure of the personnel during the event and timely recovery after the release has dispersed.

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

I.99. Protection and mitigation against the effects of internal release of hazardous substances is largely ensured by passive means (e.g. redundancy of rooms or systems, administrative 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 mitigation and coping with external hazards provided in Section 5.

II.1. SEISMIC HAZARDS

II.2. To ensure that seismic hazards 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 as recommended in Refs [6, 25]. The operating personnel should have an understanding of the importance of specific seismic safety design and analyses results and safety related components 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 SSCs to determine the status and functionality of hazard protection and mitigation features. The initiation of these procedures should be based upon indications from the seismic monitoring system, information from off-site geological monitoring centres, or ground motion experienced by the operating personnel. Insights for plant shutdown are provided in Ref. [26]. 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 to worldwide broadband seismograph networks, if necessary [27].

II.4. As a pre-event action, 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 through seismic interactions with items important to safety during a seismic event. If a seismic event and a subsequent tsunami are defined as a credible combination of hazards, the operating organization should consider the response and ensure the plant is adequately protected against the tsunami (for example, flood protection gates being in place).

II.5. If the plant is shut down after an earthquake event, the operating organization should ensure long-term safety during the shutdown phase. 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

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safety and hazard protection and mitigation features. The operating organization should check the monitoring system 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 (for the tsunami to reach the plant) and take into account the severity of seismic damage to the plant, in their post-accident management.

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

II.7. As appropriate, communication protocols with off-site geological monitoring centres should be established for redundant seismic notifications.

II.2. EXTERNAL FLOODS (STORM SURGES AND TSUNAMIS)

II.8. To ensure that external floods (storm surges and tsunamis) are included in the 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 DS498 [5].

II.9. Since external floods by storm surges or tsunamis can be forecasted to a certain extent, the operating organization should establish a warning system for external floods, including storm surges and tsunamis, and communication protocols with national and local agencies that provide forecasts, where available. The 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 vs. tsunami, far-field tsunami vs. near-field tsunami).

II.10. If communication protocols 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 pre-event, during and post-event actions corresponding 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 sea water levels should be initiated. Status of water-tight doors, bulkhead openings and water intake structures should be checked as appropriate. If necessary, actions should also be taken for any low water level conditions

(e.g. stopping operation of the seawater pump). All 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 and/or sensitive areas.

II.13. Before the flooding event, the site should be inspected for loose equipment or structures that might become flotsam and cause structural loading if they impact structures or equipment during the event. If possible, these items should be removed from the site, or secured 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, all operation and maintenance activities not related to the flooding hazard mitigation should be completed and equipment and systems should be brought into 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.

II.16. The operating organization should ensure mitigation measures such as removing debris or isolating damaged SSCs to minimize flooding propagation and to avoid increasing the damage of SSCs 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 the flooding.

II.3. EXTERNAL FLOODS (FLOODING OF RIVERS AND STREAMS, AND FLOODS DUE TO EXTREME PRECIPITATION EVENTS)

II.18. To ensure that external floods (flooding of rivers and streams, and floods due to extreme precipitation events) 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 provided in DS498 [5].

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

II.20. The operating organization should establish and implement procedures that describe pre-event, during and post-event actions corresponding to the expected amount of precipitation or in case of river flood the expected time of the different events which justify putting in place protections or to implement specific actions.

II.21. Before the flooding event, site water levels should be monitored. Status of water-tight doors, bulkhead openings and water intake structures should be checked as appropriate. The recommendation in para. II.12. for drain and waterproofing measures also should be considered.

II.22. In the case of extreme precipitation, mitigation strategies should include ensuring 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 from vital areas.

II.23. The recommendations in paras II.14–16 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 operating personnel should ensure all flood protection measures are installed and deployed as intended by design.

II.25. The recommendation in para. II.6 should be considered for extreme precipitation.

II.4. EXTREME WINDS

II.26. To ensure that extreme winds, including straight-line winds, tornadoes, extratropical or tropical storms (cyclones, hurricanes and typhoons) 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 DS498 [5].

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

II.28. The operating organization should regularly check the site meteorological systems to ensure consistency with measurements by specialized meteorological organizations as well as determining localized 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 due to the

change of the wind direction. This check can be done in the periodic update of management programmes (see Section 7).

II.29. Before any predicted extreme wind events, the operating organization should perform walkdowns and inspections of the site 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 preparatory checks of emergency power systems.

II.30. Before the extreme wind events, all operation and maintenance activities not related to this external hazard mitigation should be completed and equipment and systems should be brought into a safe condition.

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

II.32. Example check lists prepared for plant management to associate various management programmes for tropical storm are the following:

(i) When the tropical storm is approaching the plant:
- Identify the appropriate operating procedure for responding to the tropical storm, start frequent weather monitoring, conduct patrolling and if necessary, housekeeping outside the building according to the plant operation programme;
- Confirm the availability and testing log of drainage pumps (if the hazards are combined with extreme precipitation) or facilities according to the surveillance programme;
- Reconfirm the criteria for deciding to stop outdoor work by work management of the maintenance programme (or if necessary, fuel management programme);
- Establish internal and external communication systems according to the plant operation programme[8].

(ii) When the expected alert area of the extreme winds includes the plant:
- Assess whether all works can be continued by the work management according to the maintenance programme (or if necessary, fuel management programme);

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

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  - Review the list of all work, preparation progress and incorporating information from other management programmes, including plant modification management, operating experience feedback and physical protection according to the quality assurance programme (or relevant supporting functions)[8]
- Establish response teams including operators, internal firefighters and physical protection personnel in shift schedule according to the plant operation programme[8];
  - Take the roll calls and confirm the safety of all personnel including absent personnel according to the industrial safety programme.

(iii) When the storm alert is actually issued for the area including the plant:

- Stop all work except essential work for reactor safety and security, notify as necessary the external organization according to the plant operation programme[8];
  - Instruct the evacuation of non-essential plant personnel according to the industrial safety programme;
  - Ensure the stand-by state of the drainage pump according to the plant operation programme (or if necessary, according to the maintenance programme);
  - Put the SSC and severe accident facilities in stand-by state according to the accident management programme (if evaluated as necessary according to the safety assessment).

(iv) When the alert is lifted:

  - Instruct the personnel to resume works after the necessary check is completed according to the maintenance programme (or if necessary, the fuel management programme);
  - Release the response teams according to the plant operation programme[8];

II.33. If extreme precipitation is defined as a credible combination of hazards with extreme winds, the operating organization should determine whether equipment for flooding should be put in place based on the anticipated severity of hazards.

II.5. 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 and frost related phenomena, and lightning 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 provided in DS498 [5].

II.35. The operating organization should establish communications protocols and standards 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 the use of the site's meteorological systems. For example, the localized lightning strikes for some plants can be notified by a regional meteorological forecasting service which implement credible monitoring of the wide-area atmospheric stability.

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, cooling circuits (e.g. emergency cooling, cooling circuit of essential services), should be performed to ensure that the equipment is working properly and determine if 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, adding additional heating or cooling systems. The operating organization should ensure that these measures do not invalidate the plant's safety analysis for the subject areas or equipment.

II.38. If there is insufficient margin in equipment or systems, appropriate actions such as cleaning of heat exchangers or reducing pump flow should be performed. In some extreme cases, 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 features such as safety valves, blowout panels and intakes of heating, ventilation and air conditioning system. These should be cleared during and after the event. Installation of electric heaters in some vital areas should be considered.

II.40. The operating organization should have procedures in place for storing and moving snow at the site, if applicable. This should include clearing of access routes, as well as removal of snow from buildings to avoid the exceedance of design loads.

II.41. In cases of extreme ambient air temperatures, to ensure adequate energy supply of safety related equipment, diesel fuel composition should be checked and, if necessary, adjusted.

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 in an operational state.

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

II.45. When ice storm (combination of high wind and super cooled rain) is predicted in the area of the power grid from nuclear power plants, the operating organization should be prepared for the loss of external power caused by the rapid building up of an ice layer on overhead line conductors.

II.46. When subsequent persistent rainfall 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 the compound effect.

II.47. When reducing firefighting capability of an internal fire is defined as a credible combination of hazards with outside freezing conditions due to the extremely low temperatures, the operating organization should maintain the defence in depth for the internal fire hazard by alternative firefighting measures.

II.6. VOLCANISM

II.48. To ensure that volcanism is 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 provided in DS498 [5].

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

II.50. The operating organization should develop specific procedures that guide the operating personnel to determine if a plant shutdown is necessary due to volcanic activity based on the warning and established reasonable criteria, such as proximity to the volcanic plume or ashes.

II.51. Operating procedures should be developed and implemented for the inspection and removal of volcanic ash on or near SSCs. Special considerations should include equipment (such as 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 automatic screen wash equipment to prevent blockage of water intake facilities and pumps.

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

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

II.55. The operating organization should ensure sufficient spare parts are available for vital plant equipment that might be impacted by volcanic ash deposition. 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 ways to ensure the safe passage of control room operators and other operating personnel.

II.7. EXTERNAL FIRES

II.57. The guidance provided in this appendix I for internal fires is also valid for external fires. Additional specific guidance for external fires is provided in paras II.58–II.66.

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

II.59. Communications protocols and standards should be established with off-site agencies and organizations to notify the operating organization when environmental and/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 the notification of the operating organization of the occurrence but also the successful suppression of fires external to, but in close proximity to the site boundary.

II.61. In case of a notification on either the potential or the occurrence of an external fire, the operating organization should notify the on-site fire brigade and emergency response personnel

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of the potential hazard. This could result in the early deployment of emergency on-site response and fire-fighting equipment to a standby readiness condition.

II.62. If there is an external fire with the potential to inadmissibly affect the site, the on-site fire brigade should be in readiness, including performing necessary equipment and personnel preparations.

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

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

II.65. In order to minimize the impact of external fires from inadmissibly affecting the plant site, the operating organization should regularly inspect and assess the permanently and temporarily present combustible material or vehicles and the engineered structures and barriers at the site,, or in close proximity to the site boundary.

II.66. Due to the potential for toxic gases and hazardous fumes from external fires, operating procedures should be in place to ensure proper use of air monitoring equipment, isolation or realignment of plant area ventilation systems in the building for personnel habitability, cooling purposes and operability of emergency diesel generators. These procedures should be updated on a regular basis and in case of any plant modifications of relevance for this aspect.

II.8.EXTERNAL EXPLOSIONS

The recommendation in para. II.58 for communication with off-site organizations for external fires should also be considered for external explosions.

II.67. In the case of a notification about potential off-site explosions or shockwaves, heat flux, smoke and heated gases, ground and other vibratory motions and blast and missiles from explosions, the operating organization should notify the on-site fire brigade and emergency response personnel about the potential hazard. This could result to the deployment of on-site emergency response and fire-fighting equipment to a standby readiness condition.

II.9. TOXIC, RADIOACTIVE, FLAMMABLE, CORROSIVE AND ASPHYXIANT CHEMICALS AND THEIR MIXTURES IN AIR AND LIQUIDS

II.68. Communication protocols and standards should be established with off-site agencies and organizations when movements or activities with asphyxiants, toxic gases, and corrosive and radioactive fluids are planned to take place. Because the potential of the hazard increases during these times, off-site organizations within the site characterization boundaries should notify the operating personnel and emergency managers when off-site activities with asphyxiants, toxic gases, and corrosive and radioactive fluids occur (i.e. transport or movement of these materials). This allows the operating personnel to prepare for an accident that could involve these substances and could impact the site's external hazard mitigation strategies.

II.69. Operating procedures should be developed and implemented to properly monitor hazardous substances in the air, isolate the affected buildings or areas, ensure personnel habitability, cooling purposes and operability of emergency diesel generators by ventilation realignments, and protect operators in the main control room.

II.70. 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.71. There should be considerations of the need for maintaining personal protective equipment (e.g. breathing apparatus, protection suit) on-site to allow operating personnel and emergency workers to move to places of safety.

II.72. The operating organization should consider sheltering or evacuating non-essential plant personnel and the potential need for the use of external emergency response organizations to organize safe evacuation from the site.

II.10. AIRCRAFT CRASH

II.73. The operating organization should establish and maintain operating procedures and communication protocols with national or regional air traffic control organizations for immediate and/or redundant event notifications, as appropriate.

II.74. The operating organization should review and apply the site-specific requirements of the site and report any violations of "no-fly-zones" to national or regional air traffic control organizations.

II.75. If the safety assessment identifies that aircraft crashes might involve 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.76. Response to an aircraft crash will typically necessitate a response by on-site and off-site emergency workers. The operating organization should conduct routine training drills or practical exercises with off-site organizations to ensure coordination and response actions are understood by all emergency workers.

II.77. The operating organization should develop a specific procedure for action and deployment of alternative mobile equipment for spray water and electrical power supply that should be available on-site, and on-site emergency response personnel when notified of this hazard. This includes the prompt relocation of equipment and personnel from any potentially affected location to prevent an inadmissible loss of emergency response capability.

II.78. Since an aircraft accident on site might result in the generation of hazardous substances, emergency workers should consider the recommendations provided in sub-section II.9, including the use of air monitoring equipment.

II.79. The operating organization should develop a specific procedure for returning the reactor to a safe state when notified by the air traffic control organization of an aircraft crash potentially affecting the site.

II.80. The operating organization should develop a specific procedure for evacuating, relocating or sheltering non-essential plant personnel and personnel necessary for emergency response when notified by the air traffic control organization of an aircraft crash potentially affecting the site (e.g. to a bunkered supplementary control room instead of an unprotected main control room).

II.11. ELECTROMAGNETIC INTERFERENCES, INCLUDING SOLAR STORMS

II.81. Large solar storms caused by solar flares and electromagnetic pulses can affect the electrical grid, on-site electric equipment and instrumentation and control systems. The operating organization should establish communication protocols 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 mitigation measures for possible disturbances and notify the plant situation to external organizations. If necessary, the mitigation

measures should include the protection of telecommunication systems (e.g. combination of shielded phone devices and multiple satellite systems) and exercise for using those systems.

II.82. Large solar storms and electromagnetic pulses might impact the electrical grid potentially resulting in a loss of plant external power supply. In order to prepare for a loss of power supply, a sufficient emergency fuel supply should be in place at the site.

II.83. As solar flares and electromagnetic pulses might also impact on-site electric equipment for emergency power supply, such as transformers, the operating organization should perform proper monitoring, inspections and maintenance for those equipment.

II.84. The evolution of instrumentation and control in nuclear power plants includes more digital equipment and tends to increase the plant vulnerability to electromagnetic interferences. The operating organization should perform routine inspections and maintenance on shielding cables for those instrumentation and control systems.

II.12. BIOLOGICAL PHENOMENA

II.85. The operating organization should consider biological phenomena in the hazard management, as appropriate. Biological phenomena encompass the following three types of biological hazards:

- Marine or waterborne, e.g. jellyfish, seaweed, fish, mussels.
- Land-based, e.g. infestation from mice, rats, rabbits, biological debris such as fallen leaves.
- Airborne, e.g. swarms of insects, flocks of birds.

II.86. The cooling water and intake structures should be monitored continuously, to ensure that any unusual accumulation of aquatic organisms is noticed in time and that measures can be taken to avoid clogging of intake structures or unacceptable degradation of cooling water quality. Communication protocols and standards should be established with regional environmental, meteorological, and waterways agencies to identify when biological hazards might be present or expected so the operating personnel can take timely actions to mitigate the hazard.

II.87. For waterborne biological hazards, the operating organization should consider the use of chemical controls where allowed by environmental regulations.

II.88. For infestation of animals, the operating organization should identify the evidence of ingress or equipment damage while performing 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.89. For leaves and similar debris, the operating organization should perform routine inspections and walkdowns (including along the embankments of rivers, if applicable) to ensure intake structures and drainage systems or vital plant equipment remain operational.

II.90. Swarms of insects might threaten heating, ventilation, and air conditioning equipment, or emergency diesel generators by restricting airflow, thus limiting the operational capability of the equipment. The operating organization should perform inspections and cleaning of the affected equipment when this hazard occurs.

II.91. The operating organization should perform routine monitoring and dredging to ensure that the equipment for silting up in water intake remain operational.

II.13. HAZARDS BY COLLISIONS OF FLOATING OBJECTS AND HAZARDOUS LIQUID ON WATER INTAKES AND COMPONENTS OF THE ULTIMATE HEAT SINK

II.92. 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 collision with ice masses or large floating debris to provide the operating organization time to prepare for the mitigation of any associated hazards.

II.93. For prevention of ship collisions, large debris and large amounts of waterborne debris, the operating organization should establish and implement notification and response protocols with navigation and coast guard authorities.

II.94. If applicable, operating procedures should be developed and implemented to prepare and/or actuate a diverse ultimate heat sink to accommodate the potential loss of normal cooling and ultimate heat sink systems.

II.95. Operating procedures should be developed and implemented for the deployment of floating booms or curtains to intercept oil spills, or surface skimmers to keep any oil at a safe distance from water intake structures to prevent damage to plant equipment and facilitate recovery actions.

II.96. Operating procedures should be developed and implemented for the identification of potential debris accumulation in water intake structures and for performing the subsequent cleaning.

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