IAEA SAFETY STANDARDS

for protecting people and the environment

Step 7

Preparing draft

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

DS 503

DRAFT SAFETY GUIDE

Revision of NS-G-2.1and enhanced scope

FOREWORD

By Rafael Mariano Grossi

Director General

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

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

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

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

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

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

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

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

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

EDITORIAL NOTE

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

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

The English version of the text is the authoritative version.

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. This Safety Guide was prepared under the IAEA programme for establishing standards for nuclear power plants. This publication is a revision of the IAEA Safety Guide on fire safety in the operation of nuclear power plants issued in 2000 as IAEA Safety Standards Series No. NS-G-2.1, Fire Safety in the Operation of Nuclear Power Plants.

1.2. This guide extends the coverage of the earlier guide from operational management covering fire hazards to also focuses on the operational management of internal and external hazards and it is intended to be used with the set of Safety Guides related to the operation of the nuclear power plant[1].

1.3. 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 Member States. A number of other internal 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.

1.4. Potential plant- and site-specific hazards have typically been identified and analysed in various internal and external hazard analyses, as well as in probabilistic safety assessments (PSA). In addition to operating experience gained from incidents and accidents, these analyses and assessments provide insights on plant- and site-specific features related to hazards and identify potential improvements in the protection measures against hazards. These insights are valuable to ensuring adequate provisions against hazards during the whole life cycle of a nuclear power plant.

1.5. Nuclear power plants have been designed against different types of internal and external hazards [5]. However, these design features need to be complemented and maintained with operational measures to protect nuclear power plants adequately from these hazards. IAEA Safety Standards Series No. SSR-2/2 (Rev.1), Safety of Nuclear Power Plants: Commissioning and Operation [6] par 1.1 states that "The safety of a nuclear power plant is ensured by means of proper site selection, design, construction and commissioning, and the evaluation of these, followed by proper management, operation and maintenance of the plant.

[1] This Safety Guide keeps detailed recommendations of NS-G-2.1 for the internal fire hazard which is common in most nuclear power plants. As detailed application for other hazards will be site specific, the nature of main text of this Safety Guide also provides the high-level general guidance which may be applicable to a broad range of hazards, reactor types, and different operating phases.

In a later phase, a proper transition to decommissioning is required. The organization and management of plant operations ensures that a high level of safety is achieved through the effective management and control of operational activities".

1.6. This Safety Guide incorporates progress in the operation of nuclear power plants in Member States, considering lessons learned from external events in particular from the international response to the Great East Japan Earthquake and Tsunami of 11 March 2011 and its effects on the Fukushima Daiichi nuclear power plant.

1.7. The Guide also incorporates progress in regulatory practice, feedback from safety review missions and results of recent research on the impacts of external events. This Guide provides new or updated recommendations on enhanced understanding of operational aspects of hazards and combinations of hazards.

1.8. Several IAEA publications give either general design guidance, or specific design guidance for hazards. Specifically, IAEA Safety Standards Series No. SSG-64, Protection against Internal Hazards in the Design of Nuclear Power Plants (under publication)[1], IAEA Safety Standards Series No. SSG-XX, External Events Excluding Earthquakes in the Design of Nuclear Installations (Under revision, DS498)[2] and IAEA Safety Standards Series No. SSG-XX, Seismic Design of Nuclear Installations (Under revision, DS490)[3] provide design guidance for internal and external hazards respectively.

OBJECTIVE

1.9. This Safety Guide provides guidance for plant managers, operators, safety assessors of the operating organization, technical support organizations, and the regulatory body of Member States, with recommendations and guidance on suitable measures for ensuring that internal and external hazards are considered in the operation of a nuclear power plant and an adequate level of safety is maintained throughout the lifetime of a nuclear power plant. In addition, the application of the recommendations of this Safety Guide will support the fostering of a strong safety culture.

This Safety Guide is also of relevance to other organizations involved in the design, construction, commissioning, operation and decommissioning of nuclear installations, including technical support organizations, vendor companies (e.g. designers, engineering contractors, manufacturers), research establishments and universities providing research and safety related services in support of a nuclear facility.

SCOPE

1.10. The entire part of this Safety Guide applies to operational light water reactors and heavy water reactors designed and operated in accordance with the requirements provided in Specific Safety Requirement for nuclear power plants [5] [6]. For other types of nuclear reactors, including gas cooled reactors, some of the recommendations in this guide might not be fully applicable, as detailed application of these Specific Safety Requirements will also depend on the particular technology and the risks associated with internal and external hazards. This guide also applies to existing nuclear power plants designed in accordance with earlier standards, except the recommendations for the consideration of the design extension condition and the recommendations complemented by IAEA SSG-64 [1], DS498 [2], and DS490 [3]. For the consideration of the design extension condition and the referring these new standards for existing plants, it is expected that in the safety assessments of such designs (for example as part of the periodic safety review of the plant. See Requirement 12 of SSR-2/2 (Rev.1) [6]), a comparison will be made with the current standards, to determine whether the safe operation of the plant could be further enhanced for these exceptional recommendations by means of reasonably practicable safety improvements: see par. 1.3 of SSR-2/1 (Rev. 1) [5].

1.11. This Safety Guide incorporates new experience, practice and technical developments to give recommendations considering on requirements in SSR-2/2 (Rev.1) and related safety guides on the operation of nuclear power plants in the context of internal and external hazards.

1.12. This Safety Guide does not specifically discuss 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. This guide also does not discuss social or pathological hazards (e.g. pandemic[2]) which does not physically cause impact on the safety of the nuclear power plant.

1.13. Where a postulated internal and external initiating event may be caused by human actions, this Safety Guide excludes initiating events caused by deliberate human actions of malicious intent. Prevention and mitigation of malicious acts that could lead to similar events (either by on-site personnel or by third parties, e.g. terrorist incursions) are outside the scope of this document, and guidance on this issue is covered by IAEA Nuclear Safety Series.

---

[2] Pandemic affects only through humans. While consideration for the number of staff should be paid considering these situations (See. Par. 3.4.), these situations are discussed in the revision of IAEA Safety Guide for the operating organization [16] and this guide keep it separated from other external challenges.

1.14. This Safety Guide is focused on safety issues. However, safety measures and security measures must 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. Therefore, this Safety Guide also includes interfaces between nuclear safety and nuclear security. In dealing with these interfaces, it must be borne in mind that nuclear safety and nuclear security are equally important, and measures to be taken must be mutually acceptable in both areas.

STRUCTURE

1.15. Section 2 provides general considerations for protection against hazards in the operation of nuclear power plants. Section 3 focuses on the organization and responsibilities of the hazard management. Section 4 provides recommendations for ensuring safety for internal hazards while Section 5 does the same for external hazards. Section 6 provides operational guidance for the combination of internal and external hazards. Section 7 provides recommendations on updating the hazard management. Section 8 provides guidance on material control and housekeeping on the hazard management. Section 9 provides recommendations for the maintenance and testing of equipment required for hazard prevention, protection, mitigation and coping. Section 10 provides guidance on training of personnel for hazards.

Additional information is given in appendices to aid understanding of aspects of the Safety Guide; Appendix A and B gives more detailed technical aspects to be considered in internal hazards and external hazards respectively, and Appendix C provides assistance in identifying an approach towards combinations of hazards when developing the hazard management.

2. GENERAL CONSIDERATIONS

2.1. The internal and external hazards are described in par. 5.16 and 5.17 of Safety Standards Series No. SSR-2/1 (Rev. 1) [5]. Internal hazards that originate within the plant are associated with failures of facilities and activities of the operating organization. External hazards are those natural or human induced events that originate external to both the site and the processes of the operating organization, for which the operating organization may have very little or no control. Such events are unconnected with the operation of the NPP site or conduct of an activity on the site but could have an adverse effect on the safety of the NPP site or activity. Throughout this Safety Guide, the word “hazard” or “hazards” implies both these internal and external hazards, and the combination of these hazards unless where specifically noted.

2.2. The term “hazard management” imply a set of operational measures which including processes for prevention, protection, mitigation measures, and impact coping strategies for the associated hazards. The term “hazard prevention, protection and mitigation features” include safety systems and features, and also these features that were not ordinarily installed or designed as safety systems or features, unless where specifically noted. Other terminologies are consistent with the definitions in the Safety Requirements and the Safety Glossary (2018 Edition) [25].

2.3. This Safety Guide provides recommendations and guidance for the operational management aspects of preparing for, prevention, protection, mitigation and coping with hazards or those impacts at a nuclear power plant, to meet the relevant requirements of IAEA SSR-2/2(Rev.1) [6]. The followings are explanation of the connection for several requirements of SSR-2/2 (Rev.1) [6] and this guide, although other requirements are also generally relevant beyond these particularly annotated here:

Requirement 2: Management System

“The operating organization shall establish, implement, assess and continually improve an integrated management system.”

The integrated management system is required to integrate all management which include the processes for hazard prevention, protection and mitigation measures, and hazard impact coping strategies. The consideration for the management processes and programmes are discussed in Section 3.

Requirement 11: Management of modifications

“The operating organization shall establish and implement a programme to manage modifications.”

Appropriate management programme for modifications should maintain, and updated as necessary, all hazard prevention, protection and mitigation features. For this purpose, several considerations regarding to hazard management and its review are recommended in this guide. See section 3 and 7.

Requirement 12: Periodic safety review

“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.”

The review and update for hazard analysis method and developed hazard management through the periodic safety review are recommended in section 7.

Requirement 18: Emergency preparedness

“The operating organization shall prepare an emergency plan for preparedness for, and response to, a nuclear or radiological emergency.”

Requirement 19: Accident management programme

“The operating organization shall establish, and shall periodically review and as necessary revise, an accident management programme.”

The hazard prevention, protection, and mitigation measures, hazard impact coping strategies and its decision making should be harmonized with the emergency plan and accident management programme, for mitigating and coping with the event progress from internal or external hazards to a nuclear or radiological emergency. In this regard, this guide is intended to be used with IAEA GSR Part 7 and SSG-54. (See par. 3.8. of this guide.) In addition, the guidance for occupational protection against exposure of workers in a nuclear or radiological emergency is provided IAEA GSG-7 [26]. While these IAEA Safety Standards cover the recommendations focusing on the radiation-related hazards in a severe accident or radiological emergency management, this guide covers all the other means that help the operating organization ride through hazards with minimal consequences.

Requirement 22: Fire safety

“The operating organization shall make arrangements for ensuring fire safety.”

The recommendations for specific hazard prevention, protection and mitigation measures and hazard impact coping strategies in this Safety Guide is developed upon this requirement. Special attention should be paid for the application of the principle of defence in depth for fire safety. See par. 2.11. of this guide.

Requirement 23: Non-radiation-related safety

"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."

The hazard prevention, protection and mitigation measures and hazard impact coping strategies are implemented by personnel involved in activities at the plant. Therefore, the hazard management measures should be considered those personnel's industrial safety. Par. 5.26 of SSR-2/2 (Rev.1) also required that the non-radiation-related safety programmes 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.

Requirement 26: Operating procedures

"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 procedures for hazards management should be developed in line with the requirements from par. 7.1 to par. 7.6. of SSR-2/2 (Rev.1).

Requirement 28: Material conditions and housekeeping

"The operating organization shall develop and implement programmes to maintain a high standard of material conditions, housekeeping and cleanliness in all working areas."

The management and control of materials and housekeeping on a routine basis may have a non-negligible impact on the occurrence or progression of hazards and their consequences. Proper housekeeping should be in effect at any time, even if some actions are particular important only at times when an external hazard is forecast. Specifically, applicable paragraph is par. 7.10.

Requirement 31: Maintenance, testing, surveillance, and inspection programmes

“The operating organization shall ensure that effective programmes for maintenance, testing, surveillance and inspection are established and implemented.”

In the activities of maintenance, testing, surveillance and inspection, risk caused by hazards may different from risk in normal operation. Particular protection against hazards should be in place during these activities considering the availability of hazard management measures. It is also important to identify such activities and appropriately associate the management programmes which include those activities to hazard management.

Requirement 32: Outage management

“The operating organization shall establish and implement arrangements to ensure the effective performance, planning and control of work activities during outages.”

During outages including low power and shutdown operation, risk caused by hazards may different from risk in normal operation. Particular preparation for preventing, mitigating and coping with hazards should be in place during outages considering the dynamical changes of the plant conditions such as shutdown safety, protection zone (e.g. containment vessel) and increasing work resources (e.g. workers, combustibles, scaffoldings, vehicles, etc.).

Requirement 33: Preparation for decommissioning

“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.”

Provisions that ensure plant safety in the event of hazards should be maintained for the stage of decommissioning, taking into account the progress of the situation.

2.4. The hazard management that ensure plant safety in the event of hazards should be maintained current and applicable for each stage of plant life, from construction and commissioning to plant operation and through decommissioning.

2.5. Hazards caused by (or occurring at) different reactor units or different nuclear power plants at the same site should be considered. Depending on the operating organization of the different reactors, the consequences from hazards either occurring at another reactor unit on the same site or affecting more than one reactor unit at the same site have to be considered differently.

2.6. Hazards have the potential to induce initiating event to cause failures of means that are necessary to prevent significant harmful effects, and to adversely affect (directly or indirectly) the barriers to release of radioactive substance.

2.7. While it might not be practical or possible to prevent a hazard impacts from triggering an anticipated operational occurrence (AOO), one of the objectives of hazard management is to ensure that, to the extent practicable, hazards do not trigger a more severe plant state (accident condition) whenever practicable. (e.g. avoidance of multiple failure of safety system caused by a single fire event)

2.8. Proper in-service inspections should be implemented for equipment and features that cope (and, if possible, detect) with hazards (or of signs that can lead to the occurrence of an internal hazard) and implementation of necessary corrective actions to ensure protection against the hazard. Hazards should be taken into account in in-service inspections and, where necessary, additional in-service inspections should be in place for coping with hazards.

2.9. An appropriate management system should be applied to all hazard prevention, protection and mitigation features in order to reduce the potential for common cause failure and thus pose a threat to safety. This includes those that were not ordinarily installed or designed as safety systems when the plant was designed and built but provided later as modification or additional hazard mitigation features.

2.10. The following IAEA Specific Safety Guides related to each management processes or programmes contain relevant recommendations related to hazard management. Although the listed Guides are not exhaustive, operational provisions for hazard management should be consistent with these recommendations:

- IAEA Safety Standards Series No. NS-G-2.3, Modifications to Nuclear Power Plants [21][3];
- IAEA Safety Standards Series No. NS-G-2.4, The Operating Organization for Nuclear Power Plants [16];

[3] The management programmes for plant modifications may include processes relevant to the hazard management measures such as specific safety consideration for industrial hazards such as high voltages, working at heights, fire and use of chemicals or explosives, and special temporary emergency procedures in addition to the general modification management.

- IAEA Safety Standards Series No. NS-G-2.6, Maintenance, Surveillance and In-Service Inspection in Nuclear Power Plants [18][4];
- IAEA Safety Standards Series No. NS-G-2.8, Requirement, Qualification and Training of Personnel for Nuclear Power Plants [19];
- IAEA Safety Standards Series No. NS-G-2.14, Conduct of Operations at Nuclear Power Plants [13][5];
- IAEA Safety Standards Series No. SSG-25, Periodic Safety Review for Nuclear Power Plants [17]; and
- IAEA Safety Standards Series No. SSG-54, Accident Management Programmes in Nuclear Power Plants [15].

APPLICATION OF DEFENCE IN DEPTH

2.11. To ensure the concept of defence in depth of nuclear power plant according to IAEA SSR-2/1 (Rev.1) [5] against fire hazards, it is necessary to verify defence in depth for internal fire hazards in-line with corresponding operational limits and conditions (See Appendix A.1.).

2.12. The operating organization should take an active part in achieving the objectives of defence in depth by establishing procedures to operate the designed and installed prevention, protection and mitigation features for all other hazards and implementing the hazard impact coping strategies to ensure that the fundamental safety functions are maintained for all plant states.

2.13. The operating organization should consider an approach for defence in depth applicable during operation by a combination of maintaining engineered method presented in IAEA SSR-2/1 (Rev. 1) [5] and implementing procedural methods presented in IAEA SSR-2/2 (Rev.1) [6] to protect the plant from hazards.

[4] The management programme for maintenance, surveillance and in-service inspection may include processes relevant to the hazard management measures such as work control and administrative procedures for fire hazard control, surveillance programme for hazard mitigation and coping equipment, and management for storage facilities to limit the risk of fire, flooding, earthquake, missiles and release of hazardous substances.

[5] The management programme for plant operations may include processes relevant to the hazard management measures 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 such as deterioration protection systems and the status of fire doors, accumulations of combustibles, condition of flooding protection features, seismic constraints, unsecured components, and housekeeping.

3. ORGANIZATION AND RESPONSIBILITIES

3.1. Defined roles and responsibilities of personnel involved in the establishment, implementation, and administration of the hazard management should be identified, documented and maintained up to date [4] [10].

3.2. The arrangements for delegation of these responsibilities should be documented, implemented and maintained up to date [16]. The operating organization should identify the organizational structures, processes, specific responsibilities, level of authority, and interfaces of personnel involved in hazard prevention, protection and mitigation measures including their relationship with internal and external organizations, if necessary, in the form of lists or tables. The external organizations should be developed accounting for differences in site challenges, plant design aspects, and regional and national governance.

3.3. Responsibilities for deploying protective measures should be executed by plant management and operating personnel in a timely manner when hazardous conditions are forecasted (e.g., severe storm). The operating organization should identify and establish staffing levels and capabilities, and organise them appropriately, in the period prior to the event, to mitigate and cope with the hazard. For this purpose, the operating organization should have documented plans and protocols with plant personnel trained in these plans and protocols.

3.4. The operating organization should include a combination of personnel from the various site sections or organizations such as engineering, operations, maintenance, technical support and emergency response. These personnel perform activities to ensure the plant is protected by suitable design and maintenance and operated accordingly to prevent hazards and to mitigate and cope with the impacts of hazards and their consequences. The operating organization should also ensure that an adequate number of competent staff are available at all times to operate the plant safety in both normal and abnormal conditions in case of hazard and induced effects [13].

3.5. The operating organization should include a response team with the appropriate qualifications, skills and training in the use of hazard mitigation and coping equipment (See section 10).

HAZARD MANAGEMENT

3.6. The operating organization should have a set of hazard management measures to ensure that the plant can be protected from, prevent and mitigate the impact of, and cope with the consequences of hazards or credible combinations thereof, in an integrated management system. Specifically, 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.

3.7. Adequate management are required for fire safety by par. 5.21 of IAEA SSR-2/2 (Rev.1) [6]. The management for other hazards should also be integrated with the nuclear and radiation safety programme (See Requirement 23 of IAEA SSR-2/2 (Rev.1)) [6]. The set of hazard management measures should be structured, documented[6] and associated to management processes and/or programmes based on the safety assessment (as described in the IAEA Safety Glossary)[7] [4] [7] [16] [25].

3.8. The hazard management and its decision making should be harmonized with the requirements, guidance, and actions provided in the plant's emergency preparedness and response programme and accident management programme, for mitigating and coping with the event progress from hazards to a nuclear or radiological emergency. Requirements and guidance on accident management and preparedness for a nuclear or radiological emergency are given in other IAEA Safety Standards, including IAEA SSG-54 [15], GSR Part 7 [11] and GS-G-2.1 [14].

3.9. 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, and
- Strategies for coping with hazard impacts (Hazard impact coping strategies): the methods implemented or performed to deal with an adverse situation for an indefinite period of time (See par. 3.13.).

---

[6] In the plant documentation (e.g., the Final Safety Analysis Report) shared with regulatory bodies, the hazard management may be described as one management item among the chapters for other programmes or processes such as emergency preparedness and response, accident management, physical protection, operating experience feedback, training and qualification, safety assessment, etc [16]. Operational procedures for hazards may also be prepared in addition to the normal, emergency and alarm procedures [13].

[7] The way to incorporate measures for hazards into various plant management programmes can be determined based on graded approach depends on the degree of safety significance of the site specific hazards, and other factors, such as the extent and difficulty of the efforts required to implement an protection activity against those hazards, the number of related processes, the overlap of the processes and the resource optimization (see 3.4 and Fig. 1 in GSR Part 4 (Rev. 1) etc. [7]).

3.10. The operating organization should utilize all available resources to cope with hazard impacts and reduce the likelihood that impacts would propagate, become more severe, or jeopardize the fundamental safety functions.

3.11. Hazard management should be maintained applicable and relevant throughout the entire plant lifetime. The management shall be reviewed periodically and updated as necessary to ensure that the changes in the actual plant state taking into account plant modifications, changes in the site characteristics, results of research and development, new scientific knowledge, lessons learned, best practices from industry operating experience, and other plant modifications are properly accounted. The results of the review shall be used to identify and implement in a timely manner the practicable design modifications and changes in the arrangements including organization, strategies and measures.

3.12. The procedures should set out the roles of operating personnel in relation to the roles of any external organizations (e.g. plant external professional, law enforcement organizations, or voluntary fire brigades).

3.13. Hazard impact coping strategies should be developed accounting for the physical and social infrastructure around the plant, as a part of the hazard management. The strategies should account for the infrastructure of the region around a site such as road and rail, electrical grid interfaces, presence of sources of water and proximity to water ways, regional population centres and local industries, especially those that may present hazard challenges to the site. The management should also identify relevant external resources and organizations, such as local government, emergency services and response organizations and specify the type and amount of support the regional external organizations can be relied on, as well as the points of contact and methods of communication.

3.14. Separate or integrated procedures should be available for different type of hazards, and the procedures should give clear instructions for operating personnel on actions in the event of precursors and indications of hazards and potential precursors to events resulting from hazards. These actions should be primarily directed to ensuring the safety of the nuclear power plant and personnel. In some cases, strengthening of staffing, walkdown in and around the plant, as well as shutdown or power reduction of the reactors may be necessary.

3.15. Special attention should be paid to cases where there is a risk of radioactive releases as consequence of an event initiated by a hazard. The emergency arrangements of the operating and external organizations should ensure that these cases are adequately covered.

3.16. The hazard management should include provisions to ensure safety of those personnel responsible for implementing hazard prevention, protection and mitigation measures and hazard impact coping strategies. Appropriate measures should be taken for radiation protection for personnel from operating organization and external organizations intervened on the plant (e.g. fire fighters and other external personnel). The guidance for occupational protection against exposure of workers in a nuclear or radiological emergency is provided IAEA GSG-7 [26].

DECISION MAKING FOR HAZARDS

3.17. Operational decision makers at the plant should have a level of understanding for safety significance of their nuclear power plant, and how nuclear safety and hazard prevention, protection and mitigation features could be challenged by hazards, considering the result of safety assessment and graded approach [7]. This includes an understanding of hazard prevention, protection and mitigation measures and coping strategies and measures to increase the plant's resilience.

3.18. The level of understanding by operational decision makers should include the security features of the nuclear power plant that may also be affected by the impact of the hazards and the necessary mitigation measures.

3.19. The operating organization should ensure the operational decision makers at the plant can activate various established process or programmes and procedures as required to protect against potential hazards, and to be prepared to implement hazard mitigation measures and/or hazard impact coping strategies if protection fails[8]. In addition, all of the following should be considered and implemented:

- Cooperation with regional and national external organizations:

  The operating organization or decision team should establish communication arrangements in advance with appropriate external organizations to allow timely predictions of potential hazards to input into their managerial decision-making process.

  Hazard prevention, protection and mitigation measures and hazard impact coping strategies may require additional emergency equipment which may be stored off-site (sufficiently away from site) and require transport organizations to deploy them to the site. In the context of hazards, this may include equipment such as drainage pumps. Sections 4 and 5 of this Safety Guide give further examples.

- Security aspects

[8] For this purpose, 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 an efficient decision making. See an example of the list for the tropical storm in Appendix B.5.7.

Hazard management should appropriately account for security aspects (see par.1.15.) referring relevant Nuclear Security Series [12] [22] [23] [24]. The management should be developed in consultation with physical protection personnel and should include the procedures to inform the modifications to the physical protection features and procedures to notify for any hazard occurrence to security personnel to ensure the operation for both evacuation and hazard mitigation measures and hazard impact coping strategies.

- Multi-unit plant sites

For multiple reactor units co-located at the same site or being closely adjacent, either operated by one organization or managed by different operating organization, the operating organization should consider how the site and organisational configurations affects their hazard mitigation measures and hazard impact coping strategies, particularly for hazards with an increased predictability, and ensure appropriate cooperation.

3.20. When a hazardous event has occurred or hazardous conditions have been forecasted, decision making should be performed by the operating organization to ensure:

- A timely evaluation/assessment that the response criteria for specific hazards are met;
- That time-sensitive actions and confirmation of actions are to be performed in order to manage the risk imposed by the hazard;
- Identification of any required support (e.g., internal organizations, external organizations, emergency support equipment, specialized personnel);
- That the fundamental safety functions required for the appropriate plant operating mode will be maintained.
- Alternative actions if an action is unable to be performed.

4. ENSURING SAFETY AGAINST INTERNAL HAZARDS IN THE OPERATION

4.1. For a particular nuclear power plant site, internal hazards are taken into account in the design (see IAEA SSG-64 [1]) and the operation of the plant. With a few exceptions, internal hazards are prevented and mitigated to a large extent by designing and constructing engineered features. As such, an initial hazard analysis forms part of the basic design phase. This initial hazard analysis should be supplemented to account for the realisation of operational procedures for preventing, mitigating and coping with internal hazards. Site-specific aspects (particularly for both multi-unit or multi-source sites) should be also considered in the plant design against internal hazards and the operation of the plant. The hazard analysis and operating procedures should also be updated regularly over the lifetime of the plant to reflect lessons learned from operating experience. (See Section 7)

4.2. The hazard analysis should consider the impact of credible internal hazards on SSCs. This hazard analysis will form the underpinning of the hazard management (see section 3). Further recommendations on protection against internal hazards in the design of new nuclear power plants is given in SSG-64 [1].

4.3. Hazard prevention, protection and mitigation measures for internal hazards and hazard impact coping strategies should take the form of operator and equipment deployment strategies and the procedural implementation of these strategies.

4.4. The hazard management should recognise that 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, outages or modification implementation), in order to ensure that the hazard prevention, protection and mitigation measures are not reduced.

4.5. The hazard management should define roles in controlling actions for hazards. The plant operators should have a role in actuating some protection measures in place, in reducing the extent of the effects of particular hazards by plant re-alignment, or by initiating on-site actions as part of hazard impact coping strategies to address plant challenges from the hazard (such as fire-fighting or the deployment of flooding protection).

4.6. Where additional hazard mitigation equipment or personnel may need to be deployed, the hazard management should allow for and characterize means for communication with external organizations and should include aspects of training and practice drills (see Section 10).

4.7. Hazard mitigation measures and hazard impact coping strategies for internal hazards should include the following elements to be adapted to the hazard characteristics:

- Identification of response criteria for which the internal hazard needs to be commensurate with the internal hazards identified and the potential consequences;
- Identification of appropriate warning or monitoring systems and equipment for the hazard;
- Characterization 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 maintenance and inspection requirements and procedures for equipment required to cope and mitigate the hazard;
- Development and implementation of communication standards and protocols with external organizations; and
- Personnel training to ensure development of necessary skills for implementing mitigation measures.

RECOMMENDATIONS FOR SPECIFIC INTERNAL HAZARDS

4.8. Appendix A describes in more detail specific recommendations that should be incorporated into the hazard management for the following commonly considered internal hazards. Design related aspects of internal hazards for new reactors are discussed in IAEA SSG-64 [1]. For all credible internal hazards, the general recommendations given in paragraphs 4.1 through 4.6 are applicable. The following is not exhaustive but a list of common internal hazards consistent with SSG-64 [1]:

- 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

5. ENSURING SAFETY AGAINST EXTERNAL HAZARDS IN THE OPERATION

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 experiences, and if applicable, external hazards Probabilistic Risk Assessment. Levels of hazards more severe than those considered for design should also be considered in the hazard management based on the evaluation for the impact of these hazards. IAEA DS498 [2] and DS490 [3] provide general guidance on the design aspects of external hazards including hazard analysis.

5.2. Based on the external hazard impacts characterized in hazard management, potential hazard protection and mitigation measures should be identified for each hazard that will increase the viability of a hazard coping strategy for external hazard conditions. See par. 7.2 on the periodic monitoring of external hazards.

5.3. Prior to activate the established process and procedures as required to protect against potential hazards (see par. 3.19), the operating organization should put in place processes and procedures to ensure that meteorological forecasts are monitored and that the appropriate actions are taken in due time when whether-related hazardous conditions are forecasted (e.g., coastal flooding, severe storms, tornadoes, etc). For predictable or partially predictable hazards[9], the operating organization should undertake the steps listed in the paragraph 3.20. to ensure that the site is prepared in a timely manner.

5.4. Notification protocols between appropriate external organizations and the operating organization for periods of increased risks from third-party activities (e.g. rally groups, demonstrations, etc.) should be considered crucial and established in advance. These protocols should allow timely preparation to be taken by the plant organization to mitigate potential external hazards resulting from these third-party activities. The protocols should also include the consideration for events at or near the site boundary area (e.g. temporary increases in population and traffic, potential external hazards and the dispatch plan of the external organizations to those hazards, etc.) so that the operating organization can provide clear guidance for the notification and implementing pre- and post-event actions.

[9] 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.

5.5. Hazard mitigation measures and hazard impact coping strategies should take the form of operator and equipment deployment strategies and the procedural implementation of these strategies.

5.6. The hazard management should recognise that 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, outages or modification implementation), in order to ensure that the hazard protection and mitigation measures are not reduced.

5.7. Hazard mitigation measures and hazard impact coping strategies for external hazards should include the following elements to be adapted to the hazard characteristics and especially its predictability:

- Identification of a realistic predictability or warning time for the hazard and response criteria for which the internal hazard needs to be commensurate with the internal hazards identified and the potential consequences;
- Identification of appropriate warning or monitoring systems and equipment for the hazard;
- Characterization of the nuclear safety challenges and the functional risk caused by the hazard, e.g., specific equipment that may need protection from the hazard;
- Development and implementation of an operational strategy for responding to events with warning, e.g., procedures required to support anticipatory actions (this should recognize the seasonal patterns of frequency and/or magnitude of certain natural external hazards);
- Development and implementation of maintenance and inspection requirements and procedures for equipment required to cope and mitigate the hazard;
- Development and implementation of a plant strategy for responding to events without warning e.g., response actions that may be required for a particular hazard such as debris removal following a seismic event;
- Development and implementation of communication standards and protocols with external organizations; and
- Personnel training to ensure development of necessary skills for implementing mitigation measures.

5.8. The operating organization should establish operating procedures that describe pre-event, event, and post-event actions corresponding to each external hazard. In some cases, there may be sufficient time to perform preparatory actions before the hazard impacts the site. The operating organization should define and taking into account all hazards that can be generate by original hazard, also define credible combinations of hazards (see par. 6.5.).

5.9. The operating organization should take actions to prevent or mitigate the propagation of hazard effects throughout the entire site prior to (for a forecasted event) or during an external hazard that impacts a vulnerable/sensitive portion of the site. In a wider sense, this includes ensuring site access routes that may be impacted from the hazard are available and useable or by providing alternative means of site access (e.g., by boat or helicopter). Adverse working conditions due to the hazard should be taken into consideration in the operating procedures. Operator personal safety should be taken into account, particularly during an event.

5.10. There is a very wide range in the forecast capability for 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 others, there is a range of forecast availability depending on the phenomena and the forecast lead time. For example, external flood on certain large river systems can be forecast with considerable skill days to weeks in advance. Coastal flooding due to tropical and extratropical storms can be forecast hours to days in advance. Conditions favourable for formation of severe storms and tornados can be forecast with the distribution of atmospheric pressure hours in advance, but the precise location and intensity of such phenomena come with very little warning. The hazard management should consider the forecast capability for each credible external hazard and develop hazard protection, mitigation measures and hazard impact coping strategies that are consistent with the respective capability. These measures should include actions to secure loose materials or unsecured equipment to minimize the hazard impact (for high winds, tornados, etc.), and the removal of items that could prevent proper site drainage (in the event of heavy rainfall, storm surges, etc.). Communication and notification protocols and standards with off-site organizations and agencies should be implemented, and they should ensure that plant operators are aware of the likelihood of a particular hazard.

5.11. Depending upon the predictability of the external hazard and communication with off-site 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 ultimate heat sink.

5.12. Depending upon the expected severity of the external hazards and the available time, the operating organization should consider evacuating all non-essential plant personnel. Evacuation schedule should be correctly estimated, if necessary.

5.13. The operating organization should re-establish normal conditions and return if any additional personnel temporarily assigned to coping with hazards to their normal duties in a controlled manner after the cancellation of a national or regional hazard warning.

RECOMMENDATIONS FOR SPECIFIC EXTERNAL HAZARDS

5.14. For all external hazards, the general recommendations given in sections 5.1 through 5.13 are applicable. Appendix B describes in more detail special recommendations that should be incorporated into hazard management for protection against external hazards. The following is not exhaustive but a list of common external hazards consistent with IAEA DS490 [3] and DS498 [2]:

- Seismic hazards
- External floods including tsunami and storm urge
- External floods from rivers or extreme precipitation
- Extreme winds including tornados and tropical storms (Cyclones, Hurricanes, and Typhoons)
- Other extreme meteorological conditions (including lightning strike, extreme temperatures)
- Volcanism
- External fire
- External explosions
- Asphyxiant and toxic gases, corrosive chemicals, flammable vapor clouds, and radioactive fluids (release of hazardous substances)
- Aircraft crash
- Electromagnetic interference (including Solar Storm).
- Biological phenomena
- Collisions of floating bodies with water intakes and ultimate heat sink components

6. COMBINATION OF HAZARDS

6.1. The effects of combined hazards and mitigation strategies against them should be considered in the hazard management.

6.2. Any consequential effects from possible 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 mitigation measures and hazard impact coping strategies for the hazard combinations should be performance-based which defines a desired outcome and clear, measurable criteria to determine whether that outcome has been reached [1]. This Safety Guide does not prescribe steps that should be taken for each specific combination (nor does it prescribe how to combine them), but this guide provides the concepts how hazard management should be developed the performance-based measures for hazard combinations.

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 various effects. The hazard management should include information on how combinations of hazards could alter the overall situation of the plant and include information on how this is handled. Combinations of hazards can alter hazard mitigation measures and hazard impact coping strategies, operating procedures, special hazard mitigation equipment, required internal and external organizations, communication protocols, etc.

6.5. The operating organization should review their operating procedures for each individual hazard event taking into account the potential effects of the combinations of hazards considered applicable at the site. This is because operating procedures for separate hazards could contain conflicting instructions that would 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. Also, hazard combinations means that additional or specific equipment may be needed.

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. For reactors operating at the time of the combined hazard, shutdown or power reduction should be considered on the basis of the operational decision-making process performed by the operating organization. The operating personnel should then follow the site accident management programme in accordance with IAEA SSR-2/2(Rev.1) [6], and SSG-54 [15].

6.7. The operating organization should be aware of the potential for the mitigation combinations of hazards, e.g., of a hazard causing the initiation of other hazards (consequential or correlated hazards). For example, the use of water to extinguish an internal fire may cause internal flooding due to the potential accumulation of the fire extinguishing water.

6.8. Communication protocols with internal or external organizations may 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 may be required for certain hazards. If there are multiple hazards, there may be more organizations involved in the response with different roles and responsibilities. These differing 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 with systematic process to categorize hazard combinations and should then screen the hazard mitigation measures and hazard impact coping strategies on the basis of the significance of effects on the plant and occurrence frequency. For example, the hazard mitigation measures and hazard impact coping strategies for the hazards which come from consequent events are more credible and should have special attention, than the case when the hazards come from independent events. Examples are shown in Appendix C, which covers these categorized management for hazard combinations.

7. PERIODIC UPDATING OF HAZARD MANAGEMENT

7.1. The understanding of the potential effects of hazards on the plant and of importance of maintaining the fundamental safety functions should be continuously sustained while routine updating of the hazard management throughout the lifetime of the plant. This routine monitoring, maintaining and improving performances is consistent with the guidance given in IAEA NS-G-2.4 [16].

7.2. The hazard analysis method and development of hazard management should be consistent with the plant design bases and/or design assumptions. It should be reviewed and updated;

- if additional hazards or the reassessment of severity of hazards have been identified in applicable stage of plant life, or as part of a re-licensing application, or for a Periodic Safety Review [17],
- if new information shows the existing design bases (or if applicable for existing reactor, design extension conditions) may be inadequate (See par. 1.13.).

An update of hazard management should include a harmonisation with other programmes in force at the plant site such as monitoring or emergency preparedness programmes. An update should also be performed when the severity of a hazard or plant vulnerability to a hazard has not been previously recognised. For that purpose, continuous periodic monitoring of external hazards should be considered, especially at the early stage of the lifetime of the plant.

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

7.4. Although IAEA SSG-64 [1], DS498 [2] and DS490 [3] are intended as Safety Guides for new nuclear power plants, these SSGs should be used for existing plants as a benchmark for comparison when designing plant modifications, and for gap analysis when carrying out a PSR in accordance with requirement 12 in IAEA SSR-2/2 (rev.1) [6].

7.5. The operating organization should consider operating experience, and new or updated information concerning the site-specific event assumptions since current information may indicate that design basis assumptions, hazard mitigation measures or hazard impact coping strategies are not adequate. This includes the recognition that, cliff edge effects or challenges to multiple layers of defence in depth may not be identified or addressed. IAEA Safety Standards Series No. SSG-50, Operating Experience Feedback for Nuclear Installations [9] provides recommendations for implementing an operating experience programme to improve plant equipment, procedures and training by learning from hazard events that have already occurred at the installation or elsewhere.

7.6. The operating organization should recognize 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.

7.7. 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 be taken into account.

7.8. Procedures, trainings, drills, and exercises for hazard coping and mitigation strategies and measures should be periodically or each time validated and consistent with updated design assumptions or design bases from safety assessments or safety analysis. Also, 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.

7.9. Hazard impact coping strategies should be considered and updated for changes to the physical and social infrastructure around the plant site. Examples include contact information with external organizations, changes in regional population sizes and proximity to the site, electrical grid interfaces, changes of transportation routes, changes of local industries, and hydrological and geological changes.

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

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

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

8. CONTROL OF MATERIALS AND HOUSEKEEPING

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

8.2. The hazard management should include specific plant walkdown procedures for periodic, pre-event, and post-event. The implementation of plant walkdowns should be advised in the hazard management and the results of the walkdowns should be properly documented. By these walkdowns should ensure that those SSCs needed for prevention, protection and mitigation of events due to hazards and for coping with effects from hazards are in place and maintained reliably operable. General examples are listed below. Some of these actions are of particular importance at times when an external hazard (such as extreme winds or flooding) is forecast, but proper housekeeping should be in effect at all times:

- Ensuring that culverts are kept clean immediately prior to a predicted major external flooding 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 in the eventual hazard.

Further examples of actions that need to be taken, and checked during these walkdowns, have been given in Appendices A and B.

8.3. Hazard management should identify the measures needed for the management of materials and enhanced housekeeping in accordance with requirement 28 in IAEA SSR-2/2 (rev.1) [6] and NS-G-2.14 [13].

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

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

8.6. Housekeeping controls should be enhanced at different times throughout the lifetime of the nuclear power plant. This includes periods of increased risk. (e.g., just prior to coming out from an outage Or modification implementation.)

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

9.1. A comprehensive programme should be established and implemented to perform inspections, maintenance, and testing of hazard protection and mitigation measures identified in the hazard analysis in accordance with requirement 31 in IAEA SSR-2/2 (rev.1) [6] and IAEA Safety Standards Series No. NS-G-2.6, Maintenance, Surveillance and In-Service Inspection in Nuclear Power Plants [18].

9.2. The protection against and the mitigation of most internal and external hazards are performed by conservative design. Therefore, the maintenance of hazard prevention, protection and mitigation design features should be included in surveillance programmes. The operating organization should also perform regularly scheduled inspections and maintenance 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 that are relevant for the site and that require inspection, maintenance and testing to ensure their availability. Operability requirements should be set the exploitation conditions of these hazard protection measures. If the protection measures are associated in the safety analysis, the operability requirement should be in accordance with the results or assumptions of the analysis.

- For these defined operability requirements, if it cannot be met to the extent intended, the alternative measures to be taken to reduce the risk due to the unavailability should be specified (see 9.5), and the time allowed to complete the action should also be stated.
- The inspection, maintenance and testing for the site should include general hazard protection measures and protection measures that are required for specific hazards.

9.4. In general, hazard protection measures that should be inspected, maintained, and tested include the following:

- hazard detection and alarm systems;
- communication systems for use in hazard events;
- 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 and escape routes for hazard response personnel;
- respirators and protective clothing for radiological applications.

9.5. The outage or off-line of the on-site hazard protection measures by inspection, maintenance or test should be complemented by alternative measures so that an adequate level of safety is continuously maintained during these actions. The examples of alternative measures are;

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

9.6. Special considerations for off-site equipment dedicated to hazard mitigation should include:

- Protective barriers and other protection measure not located on site (e.g. dykes). Such barriers and protection measures may not be under 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 need to be included in an inspection, maintenance and testing.
- Maintenance and inspection procedures need to include the additional off-site engineered equipment which may be utilized in hazard mitigation measures and hazard impact coping strategies.
- For predictable or partially predictable hazards, the operating organization should consider pre-event inspection and/or testing on hazard mitigation equipment to ensure the availability of the equipment when the hazard event occurs.

9.7. The operating organization should consider additional combustibles as fire loads during the maintenance periods. (See Appendix. A.1.)

10. TRAINING OF PERSONNEL

10.1. Before starting work, all personnel including staff of operating organization and contractor personnel temporarily assigned to the plant should receive training in hazards that may affect the plant. Training of personnel should be performed in accordance with requirement 7 in IAEA SSR-2/2 (rev.1) [6] and the guidance in IAEA Safety Standards Series No. NS-G-2.8, Qualification and Training of Personnel for Nuclear Power Plants [19].

10.2. Specialized hazard training should be established for designated personnel involved in operations, maintenance 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, so there may need to be differing training courses provided to different groups.

10.3. The training programme should provide training to ensure that the personnel have adequate technical skills commensurate with their roles in hazard management and familiarity with the detailed procedures to be followed. 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 maintained current and reflect the current plant configuration and hazards.

10.4. This hazard training should include information regarding their responsibilities prior to, during, and following hazards events:

- Hazard safety principles at the plant, and roles and responsibilities;
- General awareness of specific hazards. This aspect is further developed in paragraph 10.5.
- Recognition of audible and visual alarm signals including fire alarms, tsunami warnings, and other alarms as applicable to the site;
- The means of exit 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 may include fire-fighting equipment, flood barrier (aqua dams, sandbags, and flood boards, etc.) and communication equipment such as satellite phones.

10.5. The specific hazard awareness training should cover the following:

Common for all hazards:

- The importance of maintaining the integrity and operability of hazard prevention, protection and mitigation features (both passive and active) by performing regularly scheduled inspections, routine and emergency maintenance of equipment, and periodic functional tests of equipment and systems;
- The design and operating details 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 the planned modifications;
- The need 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; this necessitates 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;
- Familiarization with the physical location of SSCs, preferably through a plant walkdown;
- Familiarization with the physical location of plant hazard prevention, protection and mitigation features.

For fire:

- the need 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 with hot work procedures,
- Passive fire protection: the importance of fire doors, barriers and penetrations and for working practices that respect these.

The following items are for personnel who initiate or authorize work activities involving hot work and personnel who may be assigned the duties of a fire watch.

- The hazards associated with activities such as cutting and welding which 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 they 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 (watchmen during fire sensor repairs, securing water lines or fire extinguishers while fire water systems are partially isolated, etc.).

For flood 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.
- the designated assembly point for evacuation.

For seismic event:

- the significance of field housekeeping to avoid extraneous debris or loose items.
- drill and the full-scale exercise include 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 3.8. and 10.9)

For internal flooding:

- the role of water barriers, drainage system, 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) for the leaks in diverse locations within evaluated time.

For extreme wind and other meteorological hazards:

- awareness of the hazard associated with loose items and their potential to become wind-borne missiles as well as the need of restriction for vehicle parking and equipment storage.
- the work control and evacuation scheme by meteorological alert level.
- Awareness of the potential collapse of temporary platforms and scaffolds and the need to adequately secure them.

10.6. Because certain activities may lead to additional risk 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 paragraphs 10.7 and 10.8 below.

10.7. Personnel who initiate or authorize work activities involving radioactive materials transport should be trained to ensure they are made aware of the following:

- The ambient conditions that form part of the safe operating envelope for individual fuel or waste packages and the requirement to ensure that these values are not exceeded during movement operations.
- The method by which the site receives and communicates information on forecasting for events such as extreme wind, flooding, and other hazards that could affect the plant operator’s ability to carry out the fuel or waste movement safely.
- Actions to take if a seismic event occurs during a fuel or waste movement operation 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 transfer.

EXERCISES AND DRILLS

10.8. Periodic exercises and drills should be sufficiently realistic so that the personnel have capability to cope with and respond to situations that may 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, it should be developed to practice shift change to simulate the hazard impact coping strategies. Especially for exercises of external hazards, it should be considered hat hazards may affect simultaneously, or sequentially at multiple units at the site.

10.9. 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 staff.

10.10. 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 par. 7.9.)

10.11. For fire hazards, Requirement 22 par. 5.24 of SSR-2/1 (Rev. 1) states “Periodic joint fire drills and exercises shall be conducted to assess the effectiveness of the fire response capability.” Drills or exercise should be performed with participating site personnel and, as appropriate, the staff of off-site firefighters (see par. A.1.30 – A.1.33).

REFERENCES

[1]. INTERNATIONAL ATOMIC ENERGY AGENCY, Protection against Internal Hazards in the Design of Nuclear Power Plants, IAEA Safety Standards Series No. SSG-64, IAEA, Vienna (Under publication, DS494).

[2]. INTERNATIONAL ATOMIC ENERGY AGENCY, External Events Excluding Earthquakes in the Design of Nuclear Installations, IAEA Safety Standards Series No. SSG-XX, IAEA, Vienna (Under revision, DS498)

[3]. INTERNATIONAL ATOMIC ENERGY AGENCY, Seismic Design of Nuclear Installations, IAEA Safety Standards Series No. SSG-XX, IAEA, Vienna (Under revision, DS490).

[4]. INTERNATIONAL ATOMIC ENERGY AGENCY, Leadership and Management for Safety, IAEA Safety Standards Series No. GSR Part 2, IAEA, Vienna (2016).

[5]. INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Nuclear Power Plants: Design, IAEA Safety Standards Series No.SSR-2/1(Rev. 1), IAEA, Vienna (2016).

[6]. INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Nuclear Power Plants: Commissioning and Operation, IAEA Safety Standards Series No. SSR-2/2 (Rev.1), IAEA, Vienna (2011).

[7]. INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Assessment for Facilities and Activities, IAEA Safety Standards Series No. GSR Part 4 (Rev.1), IAEA, Vienna (2016).

[8]. INTERNATIONAL ATOMIC ENERGY AGENCY, Evaluation of Seismic Safety for Existing Nuclear Installations, Safety Standards Series No. NS-G-2.13 (2009).

[9]. INTERNATIONAL ATOMIC ENERGY AGENCY, Operating Experience Feedback for Nuclear Installations, IAEA Safety Standards Series No. SSG-50, IAEA, Vienna (2018).

[10]. INTERNATIO NAL ATOMIC ENERGY AGENCY, The Management System for Nuclear Installations, IAEA Safety Standards Series No. GS-G-3.5, IAEA, Vienna (2009).

[11]. FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL CIVILAVIATION ORGANIZATION, INTERNATIONAL LABOUR ORGANIZATION, INTERNATIONAL MARITIME ORGANIZATION, INTERPOL, OECD NUCLEAR ENERGY AGENCY, PAN AMERIGAN HEALTH ORGANIZATION, PREPARATORY COMMISSION FOR THE COMPREHENSIVE

NUCLEAR-TEST-BAN TREATY ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, UNITED NATIONS OFFICE FOR THE COORDINATION OF HUMANITARIAN AFFAIRS, WORLD HEALTH ORGANIZATION, WORLD METEOROLOGICAL ORGANIZATION, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSR Part 7, IAEA, Vienna (2015).

[12]. INTERNATIONAL ATOMIC ENERGY AGENCY, Physical Protection of Nuclear Material and Nuclear Facilities (implementation of INFCIRC/225/Revision 5), IAEA Nuclear Security Series No. 27-G, IAEA, Vienna (2018).

[13]. INTERNATIONAL ATOMIC ENERGY AGENCY, Conduct of Operations at Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-2.14, IAEA, Vienna (Under revision, DS497G).

[14]. INTERNATIONAL ATOMIC ENERGY AGENCY, Arrangements for Preparedness for a Nuclear or Radiological Emergency, IAEA Standards Series No. GS-G-2.1, IAEA, Vienna (2007).

[15]. INTERNATIONAL ATOMIC ENERGY AGENCY, Accident Management Programmes in Nuclear Power Plants, Safety Standard Series No.SSG-54, IAEA, Vienna (2019).

[16]. INTERNATIONAL ATOMIC ENERGY AGENCY, The Operating Organization for Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-2.4, IAEA, Vienna (Under revision, DS497C).

[17]. INTERNATIONAL ATOMIC ENERGY AGENCY, Periodic Safety Review for Nuclear Power Plants, IAEA Safety Standards Series No. SSG-25, IAEA, Vienna (2013).

[18]. INTERNATIONAL ATOMIC ENERGY AGENCY, Maintenance, Surveillance and In-Service Inspection in Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-2.6, IAEA, Vienna (Under revision, DS497E).

[19]. INTERNATIONAL ATOMIC ENERGY AGENCY, Requirement, Qualification and Training of Personnel for Nuclear Power Plants, IAEA Safety Standards Series NS-G-2.8, IAEA, Vienna (Under revision, DS497F).

[20]. INTERNATIONAL ATOMIC ENERGY AGENCY, Seismic Hazards in site Evaluation for Nuclear Installations, IAEA Safety Standards Series No. SSG-9, IAEA, Vienna (2010).

[21]. INTERNATIONAL ATOMIC ENERGY AGENCY, Modifications to Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-2.3, IAEA, Vienna (Under revision, DS497B).

[22]. INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5), IAEA Nuclear Security Series No. 13, IAEA, Vienna (2012).

[23]. INTERNATIONAL ATOMIC ENERGY AGENCY, Engineering Safety Aspects of the Protection of Nuclear Power Plants Against Sabotage, IAEA Nuclear Security Series No. 4, IAEA, Vienna (2012).

[24]. INTERNATIONAL ATOMIC ENERGY AGENCY, Security during the Lifetime of a Nuclear Facility, IAEA Nuclear Security Series No. 35-G, IAEA, Vienna (2019).

[25]. INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Safety Glossary: 2018 Revision, IAEA, Vienna (2018).

[26]. INTERNATIONAL ATOMIC ENERGY AGENCY, Occupational Radiation Protection, IAEA Safety Standards Series No. GSG-7, IAEA, Vienna (2018).

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

This Appendix provides recommended elements of hazard management for specific internal hazards. General recommendations for mitigating and coping with internal hazards are provided in Section 4.

A.1 INTERNAL FIRES

DEFENCE IN DEPTH

A.1.1. 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; and
- Preventing the spread of those fires which have not been extinguished, thus minimizing their effects on essential plant functions.

A.1.2. By satisfying the three objectives in par. A.1.1., it should be ensured that:

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

A.1.3. The three objectives of defence in depth listed in par. A.1.1. 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

A.1.4. 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.

A.1.5. 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 may interface with the responsibilities of other individuals, and appreciation of the potential consequences of errors.

A.1.6. 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.

A.1.7. 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

A.1.8. 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 may present a risk of exposure to fire for items important to safety.

A.1.9. 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

A.1.10. 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 co-ordinating fire safety activities should be assigned to an individual personnel position, generally referred to as the fire safety co-ordinator.

A.1.11. The fire safety co-ordinator should retain the responsibility for ensuring that all fire safety activities and functions necessary for safety are effectively co-ordinated to achieve the objectives of the fire prevention and protection.

FIRE HAZARD ANALYSIS

A.1.12. 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 [1]) for which no corrective measures are taken.

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

A.1.13. Any modification that may 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.

A.1.14. The technical justification from recommended practice (IAEA SSG-64 [1]) 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

A.1.15. A review of implications for fire safety should be carried out 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.

A.1.16. Operating licenses 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.

A.1.17. 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.

A.1.18. The personnel assigned the responsibility for carrying out 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.

A.1.19. 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.

A.1.20. 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.

A.1.21. The fire hazard analysis should be reviewed and updated to reflect the modification, as appropriate.

CONTROL OF COMBUSTIBLE MATERIALS

A.1.22. 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.,

A.1.23. 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.

A.1.24. 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.

A.1.25. 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.

A.1.26. 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.

A.1.27. 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 requires in-plant review and approval of proposed work activities prior to 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).

A.1.28. 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.

For solids:

- 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.

For liquid

- 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.

A.1.29. 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:

- 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.

A.1.30. 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.

A.1.31. Administrative procedures should be established and implemented to control maintenance and modification activities that necessitate the use of a potential ignition source or that may 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 discussed earlier 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.

A.1.32. In areas containing items important to safety, work which involves the use of a potential ignition source or which may create ignition sources ("hot work") should be permitted only after consideration of the possible consequences for safety. For example, such work may be prohibited from occurring simultaneously on functionally redundant items important to safety or in the areas containing such items.

A.1.33. 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 may 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.

A.1.34. During hot work, regular inspections should be carried out 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).

A.1.35. 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.

A.1.36. 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.

A.1.37. The use of compressed gas cylinders for cutting or welding operations or other hot work should be controlled by a system of work permits.

A.1.38. Warning signs should be placed at the entrances to areas containing combustible materials to warn personnel of restrictions or access requirements and of the necessity to permanently control ignition sources.

INSPECTION, MAINTENANCE AND TESTING OF FIRE PROTECTION MEANS

A.1.39. 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

A.1.40. A fire-fighting strategy (if necessary, as preplan) 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 procedure for plant physical protection personnel.

A.1.41. 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.

A.1.42. If reliance is placed on off-site response, 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 co-ordinate and liaise with the off-site firefighter 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.

A.1.43. Where full or partial reliance for manual fire-fighting capability is placed on off-site resources, there should be proper co-ordination 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.

A.1.44. 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.

A.1.45. 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.

A.1.46. 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

A.1.47. All plant staff 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. This training should include the following topics:

- 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;
- 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;
- different types of fire extinguishing equipment provided and their use in extinguishing fires in the initial (incipient) stage.

A.1.48. Selection and appointment procedures for plant staff should establish minimum initial qualifications for all personnel involved in fire safety functions and activities which may 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

A.1.49. Fire protection features (including preventive ones) are not generally classified as hazard prevention, protection and mitigation features and thus they may 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.

A.2 INTERNAL EXPLOSIONS

A.2.1. The operating organization should consider various explosion sources when preventing, detecting, and mitigating internal explosions. Potential sources of internal explosions may 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 may also come from High Energy Arc Flashes in electrical equipment. Explosion events may also occur in conjunction with other hazards, such as fire. Section 6 and Appendix C gives additional guidance on combined and consequential hazards.

A.2.2. The potential formation of explosive atmosphere should be avoided/limited using non-flammable liquids or processes (such as water-based solvents, operating contamination monitors with inert gases, recombining hydrogen emissions from battery charging).

A.2.3. Internal Fires and Internal Explosions are similar hazards and, in developing management the recommendations from Appendix A.1 should be reviewed. As with fires, there should be enhanced controls over materials and operations during times of increased explosion risks.

A.2.4. Active and passive protection systems (such as gas detectors, blast doors, blowout panels, room and area ventilation systems, etc.) should be subject to the inspection, maintenance and testing regimes identified in the hazard management.

A.2.5. Operating procedures should play a role in preventing explosion events such as area ventilation procedures or area or system isolation procedures, and in any post-explosion event.

A.2.6. 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 that:

- 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.

A.2.7. 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 may 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 may have the potential to create explosive mixtures which can cause an explosion with ignition sources being present. The guidance provided in A.1. (Internal Fires) in par.1.22. and A.1.27-37 are applicable.

A.2.8. In areas containing items important to safety, work which involves the use of a potential ignition/explosion source or which may create ignition sources should be permitted only after consideration of the possible consequences for safety. For example, such work may be prohibited from occurring simultaneously on functionally redundant components important to safety or in the areas containing such components.

A.2.9. The operating organization should control and/or limit personnel access in areas where explosion hazards could occur such as main and auxiliary transformer areas.

A.3 MISSILES

A.3.1. Potential missile sources are present at all nuclear power plants. The operating organization efforts should focus on ensuring the integrity of potential missile sources and of engineered structures is maintained so that missile generation and hazard propagation are prevented or unlikely and limited in extent, should the hazard occur and is mitigated before it affects essential plant or system functions.

A.3.2 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)

A.3.3. The operating organization should control and/or limit personnel access in areas where missile hazards could occur.

A.3.4. 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 may include output from vibration monitors or reports of unusual sounds. Indication that an event has occurred may come from direct observation of missile effects by operating personnel, or video monitoring of plant areas.

A.3.5. 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.

A.3.6 . 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 regimes identified in the hazard management, and to plant surveillance programmes (see section 9).

A.3.7. The integrity of engineered structures and barriers affected by an internal missile hazard has to be assessed.

A.4 COLLAPSE OF STRUCTURES AND FALLING OBJECTS

HEAVY LOAD DROP

A.4.1. Analysis of these hazards should be performed in accordance with IAEA SSG-64 [1]. Although this is written as a Safety Guide for the design of new nuclear power plants, it specifically says it should be expected for existing plants that the safety assessments of such designs 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. 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 a potential hazard. Non-crane related load drops from heights may be related to mishandling of other heavy objects at height. Par. 4.170-4.183 of SSG-64 [1] provide identification, characterization, prevention and mitigation of heavy load drop.

A.4.2. 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.

A.4.3. 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 can 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 design bases; (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.

A.4.4. Communication protocols should be established between plant operators in the main control room and personnel controlling and performing the lifts where required.

A.4.5. The operating organization should establish operating procedure actions to implement the hazard prevention, protection and mitigation measures and hazard impact coping strategies when there is a high risk of damage or multiple hazard impacts (i.e. fire, flooding, etc.) following a dropped load.

A.4.6. The operating organization should establish operating procedures for performing regular walkdown and inspection of areas and structures where collapses and falling objects may occur. Those areas which are located outside plant buildings should be included for walkdown or inspection when there is a high risk of the degradation of objects in the open air or impacts of extreme winds.

A.4.7. 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.

A.4.8. Disabling of or changes to active protective measures (limiters, interlocks, trips) should only be allowed in accordance with pre-planned procedures.

A.4.9. 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.

A.4.10. The integrity of engineered structures and barriers affected by drop of loads has to be assessed.

A.5 PIPE BREAKS

A.5.1. Pipe breaks (or pressure part failure) is associated with a variety of resulting hazard phenomena, including pipe whip impacts, room pressurisation, jet effects, and flooding. The extent of each of these phenomena depends on the fluid involved, and its temperature and pressure. In accordance with the relevant requirements 10, 14, 24 and 31 of in IAEA SSR-2/2 (rev.1) [6], the actions described in the following paragraphs A.5.2. to A.5.4. should be taken preventing pipe breaks and mitigating their potential impact.

A.5.2. The operating organization should ensure the control of plant configuration for the plant piping including engineered structures designed to minimize the impact of pipe breaks is maintained at all times. For this purpose, 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 the inspection to identify general pipe and piping component degradations, and steam and water leaks. Also included in these nuclear power plant operator walkdowns should be engineered barrier integrity, pipe whip restraints, pipe hangars, blast doors, blowout panels, and drains.

A.5.3. The ageing management programme should incorporate the appropriate aspects of pipe integrity. This should include operating experience feedback regarding any new information on the potential degradation of comparable piping systems.

A.5.4. 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. Furthermore, engineered movable structures designed to minimize the impact of pipe breaks like valves, hangers, and dampers should be tested regularly proving they are functional.

A.5.5. 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.

A.5.6. When a pipe break did occur and the plant returned to a safe state, a thorough inspection should be per-formed revealing any damage that might have been caused by the different impacts of the break in its surrounding. Next to the effects mentioned above in paragraph A.5.1 this should include the internal de-pressurization wave, high humidity, spray, and high temperature in the room concerned.

A.6 INTERNAL FLOODS

A.6.1. Internal floods at a nuclear power plant may be caused by leakages, pipe breaks, tank breaches, open valves, or use of fire-fighting water. These may 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.

A.6.2. Enhanced operational controls during construction, maintenance or inspection activities should be place during times of increased flooding risks (e.g. temporary water hoses during outage period, temporary storage which causes floor area reduction).

A.6.3. Operational controls should include inspections of water-based systems for integrity before returning them to service and that any temporary modifications to drains, including temporary covers, have been restored to the pre-work conditions.

A.6.4. 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 critical 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, therefore, some flood scenarios are naturally self-limiting (for example where the flood is limited to the contents of a single tank), whereas others may require short-term actions by operating personnel.

A.6.5. General housekeeping rules control debris in drain systems, but inspections and plant walk downs should check the general condition of drainage systems (verification that it 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.

A.6.6. 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. 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 the flooding should be suitably trained to the application of these procedures (See par. 10.5).

A.7 RELEASE OF HAZARDOUS SUBSTANCES

A.7.1. Releases of on-site hazardous substances are generally viewed as unlikely, limited in extent should they occur, and can be avoided before they affect essential plant functions. However, the operating organization should consider the effects of hazardous substances on plant operators carrying out important actions, and in particular the habitability of the main control room.

A.7.2. The operating organization should establish operating procedures that characterize actions following indications of a hazardous substance release at the site. Entry into these procedures is typically based upon indications from a gas detection system, or from direct reports from operating personnel. The objective of the operating procedures should be of limiting exposure to personnel through the event and timely recovery after the release has dispersed.

A.7.3. 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 may include a partial evacuation process for personnel involved in activities at the plant. The need for on-site personal on-site protective equipment (e.g. breathing apparatus, protectiveclothing) should be considered to allow operators to move to safe plant locations.

A.7.4. 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 requirements, etc.). Operating procedures should include provisions to close dampers in the air inlet path of the ventilation system to the main control room if required, and may also include other controls over ventilation flows.

A.8 ELECTROMAGNETIC INTERFERENCE

A.8.1. All potential sources of Electromagnetic interference (EMI)[10] in the plant should be identified. Significant sources of EMI 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 may include maintenance or construction equipment and activities such as portable arc welding equipment, portable radio communications or telephony brought into the nuclear plant, and ground penetrating radar used for ground surveys.

A.8.2. Within hazard management, identification of potential EMI hazards should account for all potential sources during normal or special maintenance periods or other plant activities.

A.8.3. The EMI identification process should include the potential location of permanent and temporary sources of EMI, where possible, and focus on sources close to sensitive equipment.

A.8.4. The EMI identification process should contain controls for portable or temporary EMI sources. These controls should include the location and timing of maintenance and construction activities, and exclusion zones or other administrative or operational controls to minimize an EMI hazard, including wireless equipment used at the plant, as well as those of maintenance, repair and measuring devices.

A.8.5. The persons responsible for the activities where EMI may be generated should have a role in the management for EMI. Communications between operators and those carrying out the work may be necessary to terminate the generation source and stop further effects on the plant.

[10] 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, EMI is used as the generic term.

APPPENDIX B – TECHMICAL ASPECTS TO BE CONSIDERED IN HAZARD MANAGEMENT FOR PROTECTION AGAINST EXTERNAL HAZARDS

This Appendix provides recommended elements of hazard management for specific external hazards. General recommendations for mitigation and coping with external hazards are provided in Section 5.

B.1 Seismic Hazards

B.1.1. To ensure this external hazard is completely included in the hazard management, the operating organization for new nuclear power plant should consider and include specific actions derived from the results of the design and assessments performed on the basis of the IAEA DS490, Seismic Design for Nuclear Installations [3] and NS-G-2.13, Evaluation of Seismic Safety for Nuclear Installations [8]. Furthermore, operations personnel should understand the importance of specific seismic safety design and analyses results and safety related components and their potential failure modes, interactions, and challenges to redundancies.

B.1.2. The operating organization should develop an earthquake response plan for pre-event and post-event actions[11]. These actions take the form of procedures that describe short-term and long-term actions and include SSC specific walkdowns to determine the status and functionality of hazard protection and mitigation features. Entry into these actions is based upon indications from the seismic monitoring system, information from off-site geological monitoring centres, or ground motion experienced by operating personnel. Insights for plant shutdown are provided in the Safety Report Series[2]. The seismic monitoring system should be referred considering its emergency and reliability status, from high sensitive seismographs and strong motion accelerographs in regional and/or national monitoring network, as well as worldwide broadband seismograph networks, if necessary [20].

B.1.3. 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 pre-event action should include securing items (through seismic restraints) that may cause damage through seismic interactions with items important to safety during a seismic event.

B.1.4. If the plant is shutdown 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/damaged items important to safety and hazard protection and mitigation features.

B.1.5. If the plants surrounded by mountains or hills, operating organization should consider the post event monitoring for the condition of slopes, or sedimentation level of dams

[11] Some examples are shown in Safety Report Series No. 66, Earthquake Preparedness and Response for Nuclear Power Plants.

which built to protect the facility from landslides, and prepare measures if the unacceptable condition is observed.

B.1.6. As appropriate, communication protocols with off-site geological monitoring centres should be established for redundant seismic notifications.

B.2. Volcanism

B.2.1. To ensure this external hazard is completely included in the hazard management, the operating organization of new nuclear power plant should consider and include specific actions derived from the results of the design and assessments performed on the basis of the applicable parts of the guidance given in IAEA DS498 [2].

B.2.2. 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.

B.2.3. The operating organization should develop specific procedures that guide the operations personnel to determine if a plant shutdown is required due to volcanic activity Based on the warning and reasonable criteria (proximity to volcano plumes, ashes, etc.).

B.2.4. 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.

B.2.5. 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.

B.2.6. 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 required due to the deposition of volcanic ash.

B.2.7 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.

B.2.8. The operating organization should ensure sufficient spare parts for vital plant equipment that may be impacted by volcanic ash deposition. Special consideration should be given to the available quantities of ventilation filters.

B.2.9. The operating organization should consider the removal of volcanic ash from access ways to ensure the safe passage of plant operators and other operating personnel.

B.3. External floods including Tsunami and storm surge

B.3.1 To ensure this external hazard is completely included in the hazard management, the operating organization for new nuclear power plant should consider and include specific actions derived from the results of the design and assessments performed on the basis of the applicable parts of the guidance given in IAEA DS498 [2].

B.3.2. Since external floods by storm surge or tsunami can be forecasted to a certain extent, the operating organization should establish a warning system for external floods including tsunami and storm surge and communication protocols and standards with national and local agencies that provide forecasts, where available . The management for this hazard should consider the capability and available lead time in these forecasts differ significantly (e.g., storm surge vs. tsunami and far-field tsunami vs. near-field tsunami).

B.3.3. If communication protocols with national agencies is not available for tsunami warnings, the operating organization should consider the installation of a site-area tsunami warning system.

B.3.4. The operating organization should establish and implement procedures that describe pre-, during and post-event actions corresponding to the estimated height, arrival time, and duration of tsunami and storm surge.

B.3.5. Prior to a flooding or storm surge event, monitoring of sea water levels should be started. Status of water-tight doors, bulkhead openings and water intake structures should be checked as appropriate. Deployment of dam board and aqua dams, for example, for specific buildings should be considered. Necessary action 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 made functional. Additional waterproofing measures should also be considered for vulnerable and/or sensitive areas.

B.3.6 Prior to the flooding event, the site should be inspected for loose equipment or structures that may 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. These activities should include restraining items that may become buoyant during an extreme flooding event and block drainage outlets or access routes.

B.3.7. Prior to 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.

B.3.8. During the flooding event, operating organization should perform the following activities, with consideration of personnel safety:

- Inspection and monitoring of water levels in vulnerable and/or sensitive areas; The results should be communicated to the operating personnel.
- Water levels that could lead to overtopping of dykes, dams, or seawalls should be identified and communicated to operating personnel. Use of heavy loading equipment to remove large debris from required access areas.
-
- Isolating damaged systems and/or plant areas to minimize flooding propagation and avoid increasing the damage caused by the flooding.

B.3.9. For sites in the higher latitudes, operating organization should monitor regional ice conditions (e.g. coverage, thickness, duration, etc.) in seas and estuaries to minimize the impact by the flooding.

B.4. External floods (riverine flooding or floods due to extreme precipitation)

B.4.1. To ensure this external hazard is completely 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 applicable parts of the guidance given in IAEA DS498 [2].

B.4.2. Since external floods by extreme precipitation or 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 riverine flooding on large rivers vs. flash flooding on small watersheds vs. local intense precipitation on the site should be considered.

B.4.3. The operating organization should establish and implement procedures that describe pre-, 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 to put in place protections or to implement specific actions.

B.4.4. Prior to 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. Deployment of dam board and aqua dams, for example, for specific buildings should be considered. The recommendation in par. B.3.5. for drain and waterproofing measures also should be considered.

B.4.5. For 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.

B.4.6. The recommendations in par. B.3.7. B.3.8. and B.3.9. for activities of personnel should be considered.

B.4.7. Prior to the flooding event, the operating organization should ensure there are adequate supplies of mobile pumps, dam boards, and other necessary flood mitigation equipment.

B.4.8. The recommendation in par. B.1.5 should be considered for extreme precipitation.

B.5. Extreme winds (including Straight-line Winds, Tornadoes, Tropical storms)

B.5.1 To ensure this external hazard is completely 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 applicable parts of the guidance given in IAEA DS498 [2].

B.5.2. 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.

B.5.3. 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. Besides, 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).

B.5.4. Prior to 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.

B.5.5. Prior to 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.

B.5.6. Depending on the severity of the extreme wind hazards, the operating organization should consider evacuating all non-essential plant personnel.

B.5.7. The followings are an example of the check list prepared for plant management to associate various management programmes for toropical storm:

When the tropical storm is approaching to the plant:

- Prepare the operating procedure for means of the tropical storm, start frequent weather monitoring, conduct patrolling and if necessary, housekeeping outside the building by the plant operation programme;
- Confirm the availability and testing log of drainage pumps (if the hazards are combined with extreme precipitation) or required facilities by 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); and
- Establish internal and external communication system by the plant operation programme[12].

When the expected alert area of the extreme winds includes the plant:

- Judge whether the all works can be continued by the work management of the maintenance programme (or if necessary, fuel management programme);
- Review the all work list, preparation progress and inputting information from other management programmes including plant modification management, operating experience feedback and physical protection organized by the quality assurance programme (or relevant supporting functions)[12]

[12] These roles may be taken by the emergency preparedness and response programme or independent comprehensive operational hazard management programme.

- Establish response teams including operators, internal firefighters and physical protection staff with shift schedule by the plant operation programme[12]; and
- Take the roll calls and confirming the safety of all personnel including absent personnel by the industrial safety programme.

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 required to the external organization by the plant operation programme[12];
- Instruct the evacuation of non-essential plant personnel by the industrial safety programme;
- Ensure the stand-by state of the drainage pump by plant operation programme (or if necessary, maintenance programme); and
- Stand-by the stand-by state of the SSC and severe accident facilities by accident management programme (if evaluated as necessary by safety assessment).

When the alert is lifted:

- Instruct the resume works after the necessary check is done by the work control by the maintenance programme (or if necessary, fuel management programme);
- and
- Release the response teams by the plant operation programme[12];

B.6. Other meteorological hazards (including lightning strikes, extreme temperatures)

B.6.1 To ensure this external hazard is completely 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 applicable parts of the guidance given in IAEA DS498 [2].

B.6.2. 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 its possible duration. This information should be supplemented as necessary by the use of the site's meteorological systems. For example, the localized lightning strikes can be notified for some plants by a regional meteorological forecasting service which implement credible monitoring of the wide-area atmospheric stability.

B.6.3. In cases of extreme ambient air or water temperatures (both hot or cold), analyses or testing of equipment or systems such as pumps, fans, cooling circuits such as emergency cooling, HVAC cooling circuit etc., should be performed to ensure 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.

B.6.4. 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/closing doors, dampers, adding additional heating/cooling, etc. The operating organization should ensure these measures do not invalidate the plant's safety analysis for the subject areas or equipment.

B.6.5. If there is insufficient margin in required equipment or systems, appropriate actions such as cleaning of heat exchangers or reducing pump flow should be performed. In some extreme cases margin may only be gained by reducing reactor power.

B.6.6. Snow or large amounts of hail can block inlets or outlets of safety features such as safety valves, blowout panels and HVAC intakes. These should be cleared during and after the event. Installation of electric heaters in some vital areas should be considered.

B.6.7. The operating organization should have procedures in place for storing and moving snow at the site, if applicable. This should include clearing of required accesses, as well as removal of snow from buildings to avoid the exceedance of design loads.

B.6.8. 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.

B.6.9. 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 may be prevented by circulating warm water from the outlet circuit to the inlet.

B.6.10. The operating organization should ensure the integrity of the plant's lightning protection system is maintained in an operational state.

B.6.11. When hail is predicted, the operating organization should remove or protect as necessary vital equipment that is located outdoors.

B.6.12. When the 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 an ice layer on overhead line conductors.

B.7. Biological phenomena

B.7.1. This hazard encompasses three types of biological hazards. The operating organization should consider these appropriately in the hazard management. These types of hazards are:

-Marine/Waterborne, e.g.,

- Jellyfish
- Seaweed
- Fish
- Mussels

-Land, e.g.,

- Infestation from mice, rats, rabbits, etc.
- Biological debris such as fallen leaves

-Airborne, e.g.,

- Swarms of insects and birds

B.7.2. The cooling water and intake structures should be monitored continuously, to ensure that any unusual accumulation of aquatic organisms is noticed in time and measures can be taken to avoid clogging of intake structures or unacceptable degradation of cooling water quality. In addition, communication protocols and standards should be established with regional environmental, meteorological, and waterways agencies to identify when biological hazards may be present or expected so the plant operators can take timely actions to mitigate the hazard.

B.7.3. For waterborne biological hazards, the operating organization should consider the use of chemical controls where allowed by environmental regulations.

B.7.4. 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.

B.7.5. 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.

B.7.6. 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. Therefore, the operating organization should perform inspections and cleaning of the affected equipment when this hazard occurs.

B.7.7. The operating organization should perform routinely monitoring and dredging to ensure the equipment for silting up in water intake remain operational.

B.8. Collisions of floating bodies with water intakes and ultimate heat sink (UHS) components

B.8.1. 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. This should provide the operating organization time to prepare for the mitigation of the hazards.

B.8.2. 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.

B.8.3. 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.

B.8.4. 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. This will prevent damage to plant equipment and facilitate recovery actions.

B.8.5. Operating procedures should be developed and implemented for the identification of potential debris accumulation in water intake structures and to do the subsequent cleaning.

B.9. Electromagnetic interference (including Solar Storm)

B.9.1. Large solar storm caused by solar flares and electromagnetic pulses (EMPs) have the potential to affect the electrical grid, on-site electric equipment and instrumentation and control systems. The operating organization should establish communication protocol with the appropriate external organizations, so that the operating organization can be informed predictable solar flares by national agencies, take appropriate mitigation measures for possible disturbances, and notify the plant situation to external organizations. If necessary, the measures should include the protection of telecommunication system (e.g., combination of shielded phone devices and multiple satellite systems, etc.) and exercise for using those system.

B.9.2. Large solar storms and EMPs may 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 should be in place at the site.

B.9.3. As Solar flares and EMPs may 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.

B.9.4. The evolution of instrumentation and control in nuclear power plant to include more digital equipment tends to increase its vulnerability to EMI. The operating organization should perform routine inspections and maintenance on shielding cable for those instrumentation and control systems.

B.10. External fire

The guidance provided in Appendix A.1. of this Safety Guide for internal fires is valid for external fires. Specific guidance for external fires is provided in the following paragraphs.

B.10.1. 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 take place. 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 timely notify the operating organization before the start of such activities of the type, route and duration of the intended activities. This allows the plant operators 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.

B.10.2. 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 (i.e. dry conditions, high winds, local festivals).

B.10.3. 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.

B.10.4. In case of a notification on either the potential or the occurrence of an external fire (see B.10.1-3), the operating organization should notify the on-site fire brigade and emergency response personnel of the potential hazard. This includes the early deployment of emergency on-site response and fire-fighting equipment to a standby readiness condition.

B.10.5. If there is an external fire with the potential to inadmissibly affect the site, the on-site fire brigade should be in readiness. This includes performing necessary equipment and personnel preparations.

B.10.6. Response to external fires will typically require 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.

B.10.7. 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, etc.) in place designed to prevent as far as possible spreading of external fires to the site and to fires of site-external origin, as appropriate.

B.10.8. 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 at the site, the engineered structures and barriers, or in close proximity to the site boundary.

B.10.9. 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 buildings plant area ventilation systems 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.

B.11. External explosion including Missiles and Shockwaves

B.11.1. The recommendation in par. B.10.1 for communication with off-site organizations for external fires should also be considered for explosions.

B.11.2. In case of a notification of potential off-site explosions or shockwaves, the operating organization should consider notifying the on-site fire brigade and emergency response personnel of the potential hazard. This includes the deployment of on-site emergency response and fire-fighting equipment to a standby readiness condition.

B.12. Accidental aircraft crash

B.12.1. The operating organization should establish and maintain operating procedures and communications with national or regional air traffic control organizations. Communication protocols with air traffic control should be established for immediate and/or redundant event notifications, as appropriate.

B.12.2. 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.

B.12.3. Aircraft crashes will most likely involve the use of off-site firefighters and emergency response personnel. Thus, the operating organization should establish, maintain, and implement communication protocols to ensure efficient response by required off-site personnel.

B.12.4. Response to an aircraft crash will typically require a response from on-site and off-site emergency workers. As such, 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.

B.12.5. The operating organization should develop a specific procedure for action and deployment of alternative mobile equipment for spray water and electrical power supply, and on-site emergency response personnel when notified of this hazard. This should be available on site. This includes the prompt relocation of equipment and personnel from any potentially affected location to prevent an inadmissible loss of emergency response capability.

B.12.6. Since an aircraft accident on site may include the generation of hazardous substances, emergency workers should consider the recommendations provided in Section B.13. This includes the use of air monitoring equipment.

B.12.8. The operating organization should develop a specific procedure for bringing the reactor in a safe state when notified by the air traffic control organization of an aircraft crash potentially affecting the site.

B.12.9. The operating organization should develop a specific procedure for evacuating or sheltering non-essential (with respect to nuclear safety) plant personnel and personnel necessary for emergency response. The procedure should be developed and implemented to relocate those personnel 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.

B.13. Release of hazardous substances (Toxic, radioactive, flammable, corrosive and asphyxiant chemicals and their mixtures in air)

B.13.1. 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 will take place. Because the potential of the hazard increases during these times, it is imperative that off-site organizations within the site characterization boundaries notify plant operators 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 plant operators to prepare for an accident that could involve these substances and impact the site's external hazard mitigation strategies.

B.13.2. Operating procedures should be developed and implemented to properly monitor hazardous substances in air, isolate the affected buildings, areas, or to ensure personnel habitability, Cooling purposes and operability of emergency diesel generators by ventilation realignments. This includes protecting plant operators in the main control room.

B.13.3. Operating procedures should be developed and implemented to ensure the hazard will not propagate to unaffected buildings and areas by closing openings to unaffected buildings and areas, including windows and doors.

B.13.4. There should be considerations of the need for on-site personal protective equipment (e.g. breathing apparatus, protection suit) to allow plant operators and emergency workers to move to places of safety.

B.13.5. 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 organise safe evacuation from the site.

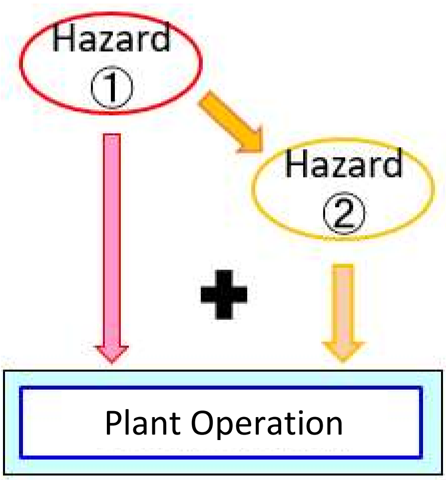
APPPENDIX C – EXAMPLES OF TECHNICAL ASPECTS TO BE CONSIDERED IN THE HAZARD MANAGEMENT FOR PROTECTION AGAINST HAZARD COMBINATION

This Appendix provides recommendations for the operational management of combinations of internal and/or external hazards. It also gives examples to illustrate how to consider these cases of impacts from hazard combinations as part of the hazard management.

C.1. The following paragraphs characterize the example of consideration in hazard prevention, protection and mitigation measures and hazard impact coping strategies for different types of impact for plant operation from combinations of hazards, that may be applicable to the site and plant under consideration and should be considered in the hazard management.

OPERATIONAL ASPECTS FOR CONSEQUENTIAL (SUBSEQUENT) HAZARDS

C.2. An initial event, e.g. an external or internal hazard, that affects the plant subsequently results in one or more other events, e.g. external or internal hazards that also affects the plant operation in different way.



Example Combination:

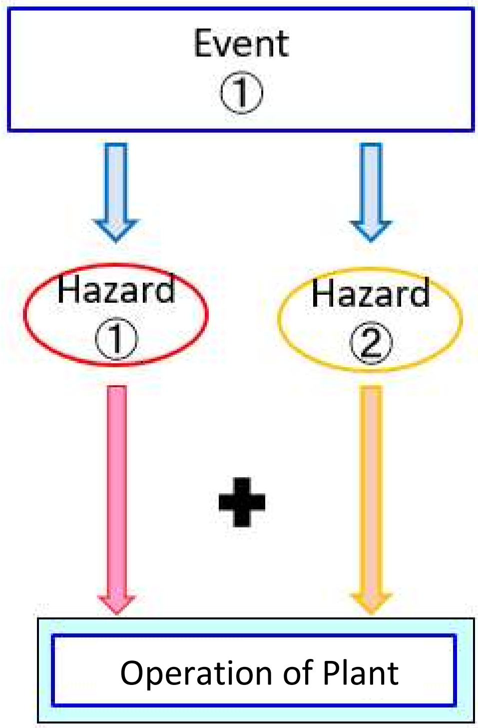
- An internal fire and subsequent internal flooding
- A seismic event and subsequent internal fire
- A seismic event and subsequent tsunami

In case of a plant internal fire event the operating organization should keep in mind that a successful firefighting may cause an internal flooding inadmissibly affecting items important to safety (e.g., measuring converters on the bottom level of the reactor annulus). Measures to prevent adverse effects from such consequential flooding should be foreseen and taken depending on the event sequence.

If an earthquake occurs, operating organization should consider the response on ensuring the plant is adequately protected against the tsunami (for example, flood protection gates being in place). Besides, the decision making should be done for the assessment of the earthquake damage, considering the lead time for the tsunami to reach the plant and the severity of seismic damage to the plant.

OPERATIONAL ASPECTS FOR CORRELATED EVENTS

C.3. Two or more events, e.g. external or internal hazards which occur at the same time-frame as a result of a common cause. The common cause can be any anticipated event including an external hazard or might be due to an unanticipated dependency. The two or more events connected by this common cause could occur simultaneously .



Example Combination:

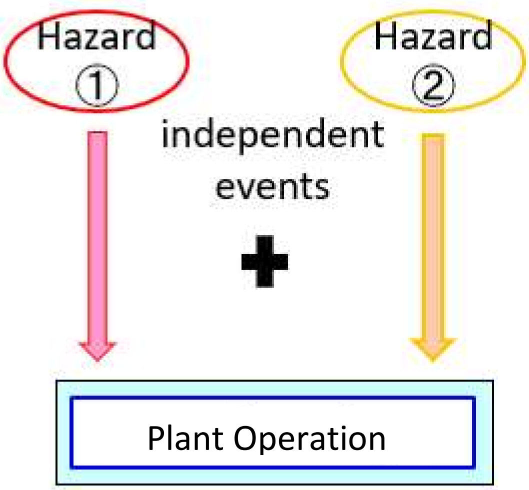
- Meteorological conditions such as storms that intrinsically involve the combination of several phenomena such as rainfall, wind, and storm surge.

Operational Aspects are for the first example:

- In this case, the operating organization should use their judgment to determine whether emergency response equipment such as aqua dams should be put in place. The decision will be based on whether the risk from storm surge is estimated to be higher than the risk from extreme rainfall (an aqua dam could prevent rainwater from draining away from the site, aggravating the effects of the hazard).

OPERATIONAL ASPECTS FOR UNRELATED (INDEPENDENT) EVENTS

C.4. An initial event, e.g. an external or internal hazard, occurs independently from (but simultaneously with) another hazard without any common cause (coincident events).



Example Combination:

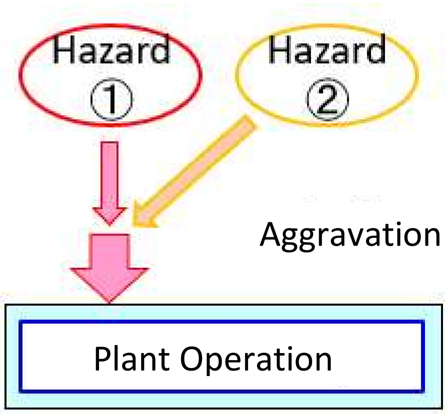
- A seismic event and extreme outside air temperature
- An external flooding and an internal fire

Operational Aspects for the examples:

- In these examples, there is no causal relation between the two events. The operating organization should maintain situational awareness when responding to hazards and use their judgment based on the performance of response organizations and the conditions in which they are operating at the time of response.

CONSIDERATION FOR AGGRAVATION OF IMPACTS BY OTHER HAZARDS

C.5. The operating organization should consider the case that one or more hazards may aggravate other hazards. This is subcategory of previous types of hazard combination.



Example Combination: Freezing conditions or persistent rain that can affect drainage conditions during subsequent rainfall.

Operational Aspects: The operating organization should ensure that installed drains have been properly cleared to prevent this type of compound effect.

C.6. For all types of hazard combinations, it is the duration of the consequential effects of each hazard that should be considered in hazard prevention, protection and mitigation measures and hazard impact coping strategies, rather than the duration of the hazard itself. For example, a seismic event may last just a few tens of seconds, but the overall hazard prevention, protection and mitigation measures or hazard impact coping strategies by personnel who required the responses 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 from the case the plant could have enough time duration to repair the damage from the earthquake. The plant responses for these case can be based on not only the response criteria for both individual hazards, but the performance of each management measures.

C.7. If the effect of hazard combinations has the potential to challenge the defence in depth strategy of the plant, the operating organization should take this into account when considering whether or not to screen an action for a particular hazard combination into the hazard management. An example of this is outside freezing conditions (the hazard) that may reduce fire-fighting capability (mitigation measure) of an internal fire (another hazard).

CONTRIBUTORS TO DRAFTING AND REVIEW

Cavellec, R.	International Atomic Energy Agency
Jiang, F.	International Atomic Energy Agency
Macleod T. M.	Office for Nuclear Regulation, United Kingdom
Maekelae, K.	International Atomic Energy Agency
Morgan, S.	International Atomic Energy Agency
Rantakaulio, A.	Fortum, Finland
Schwartzbeck, R.	Highland TEMS, United States of America
Sugahara, J.	International Atomic Energy Agency
Takiguchi, T.	Tokyo Electric Power Company Holdings, Japan
Tanabe, K.	Tokyo Electric Power Company Holdings, Japan
Tarren, P.	International Atomic Energy Agency
Wendt, O.	Vattenfall, Sweden
Williams, G.	Office for Nuclear Regulation, United Kingdom
Zahradka, D.	International Atomic Energy Agency