

IAEA Safety Standards

for protecting people and the environment

Accident Management Programmes for Nuclear Power Plants

Specific Safety Guide

No. SSG-54



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

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ACCIDENT MANAGEMENT
PROGRAMMES FOR
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The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

IAEA SAFETY STANDARDS SERIES No. SSG-54

ACCIDENT MANAGEMENT PROGRAMMES FOR NUCLEAR POWER PLANTS

SPECIFIC SAFETY GUIDE

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2019

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FOREWORD

by Yukiya Amano
Director General

The IAEA's Statute authorizes the Agency to “establish or adopt... standards of safety for protection of health and minimization of danger to life and property” — standards that the IAEA must use in its own operations, and which States can apply by means of their regulatory provisions for nuclear and radiation safety. The IAEA does this in consultation with the competent organs of the United Nations and with the specialized agencies concerned. A comprehensive set of high quality standards under regular review is a key element of a stable and sustainable global safety regime, as is the IAEA's assistance in their application.

The IAEA commenced its safety standards programme in 1958. The emphasis placed on quality, fitness for purpose and continuous improvement has led to the widespread use of the IAEA standards throughout the world. The Safety Standards Series now includes unified Fundamental Safety Principles, which represent an international consensus on what must constitute a high level of protection and safety. With the strong support of the Commission on Safety Standards, the IAEA is working to promote the global acceptance and use of its standards.

Standards are only effective if they are properly applied in practice. The IAEA's safety services encompass design, siting and engineering safety, operational safety, radiation safety, safe transport of radioactive material and safe management of radioactive waste, as well as governmental organization, regulatory matters and safety culture in organizations. These safety services assist Member States in the application of the standards and enable valuable experience and insights to be shared.

Regulating safety is a national responsibility, and many States have decided to adopt the IAEA's standards for use in their national regulations. For parties to the various international safety conventions, IAEA standards provide a consistent, reliable means of ensuring the effective fulfilment of obligations under the conventions. The standards are also applied by regulatory bodies and operators around the world to enhance safety in nuclear power generation and in nuclear applications in medicine, industry, agriculture and research.

Safety is not an end in itself but a prerequisite for the purpose of the protection of people in all States and of the environment — now and in the future. The risks associated with ionizing radiation must be assessed and controlled without unduly limiting the contribution of nuclear energy to equitable and sustainable development. Governments, regulatory bodies and operators everywhere must ensure that nuclear material and radiation sources are used beneficially, safely and ethically. The IAEA safety standards are designed to facilitate this, and I encourage all Member States to make use of them.

THE IAEA SAFETY STANDARDS

BACKGROUND

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

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

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

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

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

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

THE IAEA SAFETY STANDARDS

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

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

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

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

Safety Fundamentals

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

Safety Requirements

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

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

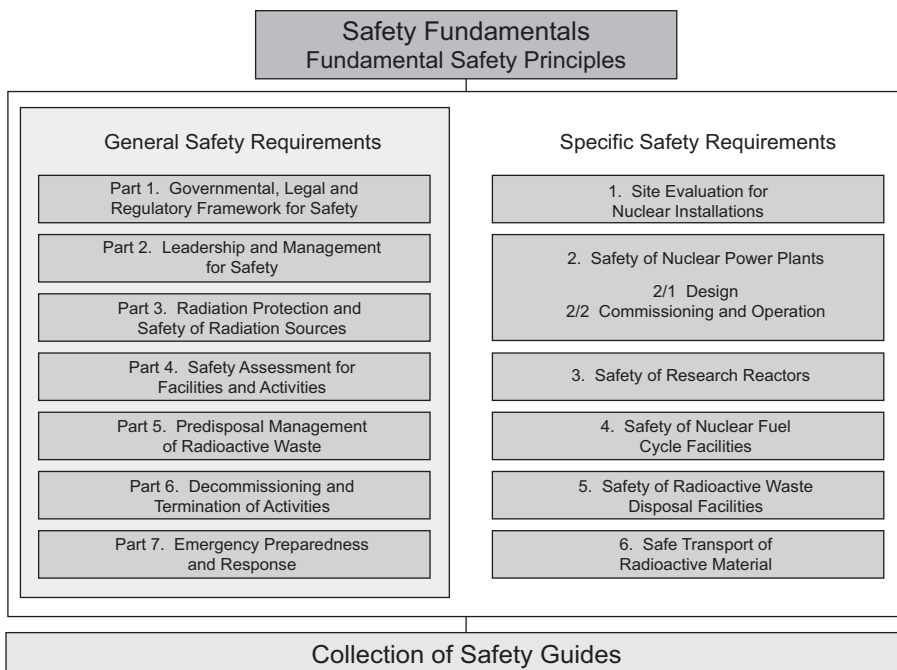


FIG. 1. The long term structure of the IAEA Safety Standards Series.

Safety Guides

Safety Guides provide recommendations and guidance on how to comply with the safety requirements, indicating an international consensus that it is necessary to take the measures recommended (or equivalent alternative measures). The Safety Guides present international good practices, and increasingly they reflect best practices, to help users striving to achieve high levels of safety. The recommendations provided in Safety Guides are expressed as ‘should’ statements.

APPLICATION OF THE IAEA SAFETY STANDARDS

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

The IAEA safety standards are applicable, as relevant, throughout the entire lifetime of all facilities and activities — existing and new — utilized for peaceful purposes and to protective actions to reduce existing radiation risks. They can be used by States as a reference for their national regulations in respect of facilities and activities.

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

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

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

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

DEVELOPMENT PROCESS FOR THE IAEA SAFETY STANDARDS

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

All IAEA Member States may nominate experts for the safety standards committees and may provide comments on draft standards. The membership of

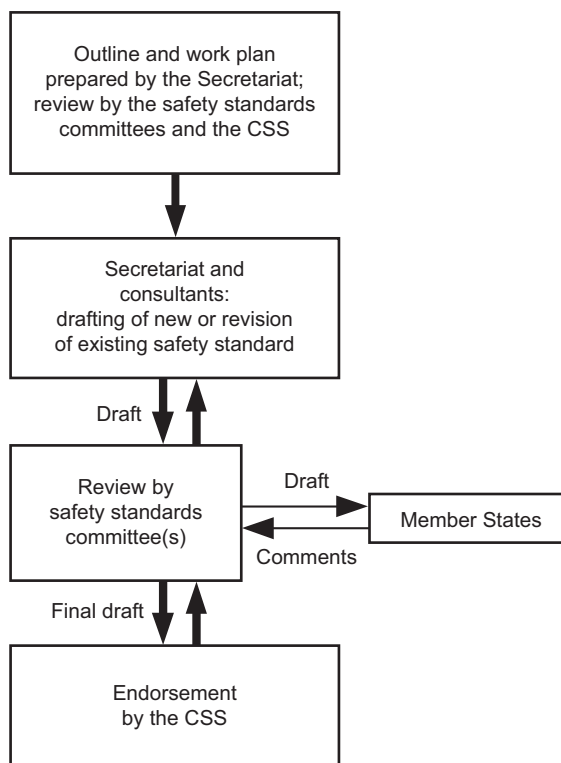


FIG. 2. The process for developing a new safety standard or revising an existing standard.

the Commission on Safety Standards is appointed by the Director General and includes senior governmental officials having responsibility for establishing national standards.

A management system has been established for the processes of planning, developing, reviewing, revising and establishing the IAEA safety standards. It articulates the mandate of the IAEA, the vision for the future application of the safety standards, policies and strategies, and corresponding functions and responsibilities.

INTERACTION WITH OTHER INTERNATIONAL ORGANIZATIONS

The findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the recommendations of international

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

INTERPRETATION OF THE TEXT

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

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

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

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

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1. INTRODUCTION

BACKGROUND

1.1. This Safety Guide was prepared under the IAEA's programme for establishing safety standards. This Safety Guide revises and supersedes the Safety Guide on Severe Accident Management Programmes for Nuclear Power Plants, which was issued in 2009 as IAEA Safety Standards Series No. NS-G-2.15¹. The current Safety Guide provides guidance on setting up a severe accident management programme, from the conceptual stage to the development of a complete set of procedures and guidelines.

1.2. The IAEA Safety Glossary [1] defines 'accident management' as:

“The taking of a set of actions during the evolution of an accident:

- (a) To prevent escalation to a severe accident;
- (b) To mitigate the consequences of a severe accident;
- (c) To achieve a long term safe stable state.”²

1.3. Accident management, including severe accident management, is therefore an essential component of the application of defence in depth [2–5]. Accident management complements the operating procedures that “**shall be developed... (for the reactor and its associated facilities) for normal operation, anticipated operational occurrences and accident conditions**”, as stated in Requirement 26 of IAEA Safety Standards Series No. SSR-2/2 (Rev. 1), Safety of Nuclear Power Plants: Commissioning and Operation [6].

1.4. Requirement 19 of SSR-2/2 (Rev. 1) [6] states that “**The operating organization shall establish, and shall periodically review and as necessary revise, an accident management programme.**” As stated in para. 5.8 of SSR-2/2 (Rev. 1) [6], the accident management programme shall “[cover] the preparatory measures, procedures and guidelines, and equipment that are necessary for

¹ INTERNATIONAL ATOMIC ENERGY AGENCY, Severe Accident Management Programmes for Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-2.15, IAEA, Vienna (2009).

² A 'long term safe stable state' is a plant state following an anticipated operational occurrence or accident conditions in which the reactor is subcritical and the fundamental safety functions can be ensured to be in and can be maintained in a stable condition for a long time.

preventing the progression of accidents, including accidents more severe than design basis accidents, and for mitigating their consequences if they do occur.”

1.5. An accident management programme encompasses plans and actions undertaken to ensure that the plant personnel and other operating organization personnel with responsibilities for accident management are adequately prepared to decide on and implement effective on-site actions. The accident management programme needs to be well integrated with the arrangements for emergency preparedness and response established in accordance with, for example, IAEA Safety Standards Series No. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency [7]; IAEA Safety Standards Series No. GSG-2, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency [8]; and IAEA Safety Standards Series No. GS-G-2.1, Arrangements for Preparedness for a Nuclear or Radiological Emergency [9], in terms of human resources, equipment and strategy.

1.6. If an accident occurs at a nuclear power plant, to restore safety, two types of accident management guidance document are typically used: emergency operating procedures (EOPs) for preventing fuel rod degradation, and severe accident management guidelines (SAMGs) for mitigating significant fuel rod degradation when a severe accident is imminent.³ The development of SAMGs is an essential part of the severe accident management programme.

1.7. Depending on the plant state during an accident, actions are prioritized as follows:

- (a) *Preventive domain of accident management.* Before the onset of fuel rod degradation, priority is given to preventing the escalation of the accident into a severe accident. In this domain, actions are implemented to stop the accident progressing to the onset of significant fuel rod degradation or to delay the time at which significant fuel rod degradation happens and preserve all the fundamental safety functions.

³ In this Safety Guide, the term ‘accident management guidance’ is used to cover both EOPs and SAMGs. Paragraphs 2.42–2.55 elaborate on the differences between EOPs and SAMGs.

- (b) *Mitigatory domain of accident management.* When plant conditions indicate that significant fuel rod degradation is imminent or in progress, priority is given to mitigating the consequences of the severe accident through:
- (i) Maintaining the integrity of the remaining fission product barriers, particularly the containment, which depending on the design can also include maintaining the integrity of the reactor pressure vessel⁴;
 - (ii) Avoiding or limiting fission product releases to the environment;
 - (iii) Returning, to the extent possible, to a long term safe stable state.

Characteristics of the preventive and mitigatory domains of accident management are summarized in the Appendix.

OBJECTIVE

1.8. This Safety Guide provides recommendations for the development and implementation of an accident management programme to meet the requirements for accident management that are established in sections 3 and 5 of SSR-2/2 (Rev. 1) [6]; sections 2 and 5 of IAEA Safety Standards Series No. SSR-2/1 (Rev. 1), Safety of Nuclear Power Plants: Design [3]; section 4 of IAEA Safety Standards Series No. GSR Part 4 (Rev. 1), Safety Assessment for Facilities and Activities [10]; and Requirement 8 of GSR Part 7 [7], to the extent that these requirements address an imminent or ongoing severe accident. The recommendations are aimed at preventing or mitigating the consequences of accidents with or without damage to the nuclear fuel, whether they are accidents within the design basis or beyond the design basis, including accidents originated by external events.

1.9. This Safety Guide is intended primarily for use by operating organizations of nuclear power plants and their support organizations. It may also be used by national regulatory bodies and technical support organizations as a reference for developing their relevant safety requirements and for conducting review and assessment.

⁴ For CANDU reactors, the equivalent objective is to maintain the integrity of pressure tubes and calandria tubes.

SCOPE

1.10. This Safety Guide provides recommendations for the development and implementation of an accident management programme for a nuclear power plant, including all possible fuel locations, particularly the reactor and the spent fuel pool. This Safety Guide is not intended to provide information on the design of structures, systems and components to address design extension conditions, although the capabilities of some structures, systems and components are key in successfully managing a severe accident. For information on this topic, refer to section 5 of SSR-2/1 (Rev. 1) [3].

1.11. This Safety Guide provides recommendations for an accident management programme on the site. It does not include consideration of all aspects of emergency preparedness and response, which is addressed in GSR Part 7 [7].

1.12. Although the recommendations of this Safety Guide have been developed primarily for use with water cooled reactors, many of the recommendations provided are generic. The recommendations of this Safety Guide may also be applied with judgement to other types of nuclear installation, including research reactors and nuclear fuel cycle facilities (including facilities for the storage of spent nuclear fuel).

STRUCTURE

1.13. This Safety Guide consists of four sections, one appendix and one annex. Section 2 presents the general recommendations for an accident management programme and is organized by topic. More detailed, specific recommendations for the development and implementation of a severe accident management programme are provided in Section 3. Section 3 is organized to follow the development process of a severe accident management programme. Recommendations on the execution of SAMGs are provided in Section 4. The Appendix provides a summary of all aspects of an accident management programme. Examples of the implementation of SAMGs in different States are provided in the Annex.

2. GENERAL GUIDANCE FOR AN ACCIDENT MANAGEMENT PROGRAMME

APPLICABLE REQUIREMENTS

2.1. Requirement 19 on accident management in the operation of nuclear power plants in SSR-2/2 (Rev. 1) [6] states: **“The operating organization shall establish, and shall periodically review and as necessary revise, an accident management programme.”** SSR-2/2 (Rev. 1) [6] also states:

“5.8. An accident management programme shall be established that covers the preparatory measures, procedures and guidelines, and equipment that are necessary for preventing the progression of accidents, including accidents more severe than design basis accidents, and for mitigating their consequences if they do occur. The accident management programme shall be documented and shall be periodically reviewed and as necessary revised.

.....

“5.8B. The accident management programme shall include instructions for the utilization of available equipment — safety related equipment as far as possible, but also items not important to safety (e.g. conventional equipment).

.....

“5.8D. The accident management programme shall include the technical and administrative measures necessary to mitigate the consequences of an accident.

“5.8E The accident management programme shall include training necessary for implementation of the programme.”

2.2. Paragraph 2.8 of SSR-2/1 (Rev. 1) [3] states:

“To achieve the highest level of safety that can reasonably be achieved in the design of a nuclear power plant, measures are required to be taken to do the following, consistent with national acceptance criteria and safety objectives [2]: ...To ensure that the likelihood of occurrence of an accident with serious radiological consequences is extremely low and that the radiological consequences of such an accident would be mitigated to the fullest extent practicable.”

2.3. Paragraph 2.10 of SSR-2/1 (Rev. 1) [3] states:

“Measures are required to be taken to ensure that the radiological consequences of an accident would be mitigated. Such measures include the provision of safety features and safety systems, the establishment of accident management procedures by the operating organization and, possibly, the establishment of off-site protective actions by the appropriate authorities, supported as necessary by the operating organization, to mitigate exposures if an accident occurs.”

2.4. Paragraph 2.13(4) of SSR-2/1 (Rev.1) [3] (footnote omitted) states:

“The purpose of the fourth level of defence is to mitigate the consequences of accidents that result from failure of the third level of defence in depth. This is achieved by preventing the progression of such accidents and mitigating the consequences of a severe accident. The safety objective in the case of a severe accident is that only protective actions that are limited in terms of lengths of time and areas of application would be necessary and that off-site contamination would be avoided or minimized. Event sequences that would lead to an early radioactive release or a large radioactive release are required to be ‘practically eliminated’.”

2.5. Paragraph 5.6 of GSR Part 4 (Rev. 1) [10] requires that “The results of the safety assessment shall be used as an input into planning for on-site and off-site emergency response [7] and accident management”.

2.6. Paragraph 5.25 of GSR Part 7 [7] states:

“arrangements shall be made for mitigatory actions to be taken by the operating personnel, in particular:

- (a) To prevent escalation of an emergency;
- (b) To return the facility to a safe and stable state;
- (c) To reduce the potential for, and to mitigate the consequences of, radioactive releases or exposures.”

2.7. Paragraph 5.25 of GSR Part 7 [7] further states:

“Arrangements shall include emergency operating procedures and guidance for operating personnel on mitigatory actions for severe conditions (for a nuclear power plant, as part of the accident management programme [6])

and for the full range of postulated emergencies, including accidents that are not considered in the design and associated conditions.”

CONCEPT OF AN ACCIDENT MANAGEMENT PROGRAMME

2.8. An accident management programme consists of all activities and processes developed and undertaken by an operating organization to meet the requirements set out in paras 2.1–2.7 for the prevention and mitigation of accidents. Severe accident management programmes are focused solely on the mitigation of severe accidents. More detailed recommendations on severe accident management programmes are provided in Section 3 of this Safety Guide.

2.9. An accident management programme should be developed and implemented for the prevention and mitigation of severe accidents, irrespective of the frequency of accident sequences or of the fission product releases considered in the design.

2.10. The accident management programme should be developed and maintained consistent with the plant design and its current configuration. The accident management programme should be periodically reviewed and revised, when appropriate, to reflect operating experience (including major lessons identified), changes of plant configuration and new results from relevant research. For example, the periodic review of the accident management programme may be accomplished as part of the periodic safety review of the plant [11].

2.11. The accident management programme should address all modes and states of operation and all fuel locations, including the spent fuel pool, and should take into account possible combinations of events that could lead to an accident. The accident management programme should also consider external hazards more severe than those considered for the design, derived from the site hazard evaluation, that could result in significant damage to the infrastructure on the site or off the site which would hinder actions needed to prevent imminent significant degradation of the fuel rods or to mitigate significant fuel rod degradation (see para. 5.8 of SSR-2/2 (Rev. 1) [6]).

2.12. A structured top-down approach should be used to develop the accident management guidance. This approach should begin with the objectives (including the identification of plant challenges and plant vulnerabilities) and the strategies, followed by measures to implement the strategies. In combination, these strategies and measures should include consideration of plant capabilities.

Finally, procedures and guidelines should be developed to implement these strategies and measures. Accident management guidance should cover both the preventive and the mitigatory domains. Figure 1 illustrates the top-down approach to accident management.

2.13. When considering objectives on the basis of the vulnerability assessment, accident management strategies should be developed for each individual plant challenge or plant vulnerability. These strategies should take into consideration plant capabilities and an understanding of accident phenomena (see Section 3).

2.14. Multiple strategies should be identified, evaluated and, when appropriate, developed to achieve the objectives of accident management, which include:

- (a) Preventing or delaying the occurrence of fuel rod degradation;
- (b) Terminating the progress of fuel rod degradation once it has started;
- (c) Maintaining the integrity of the reactor pressure vessel to prevent melt-through, especially at high pressure;

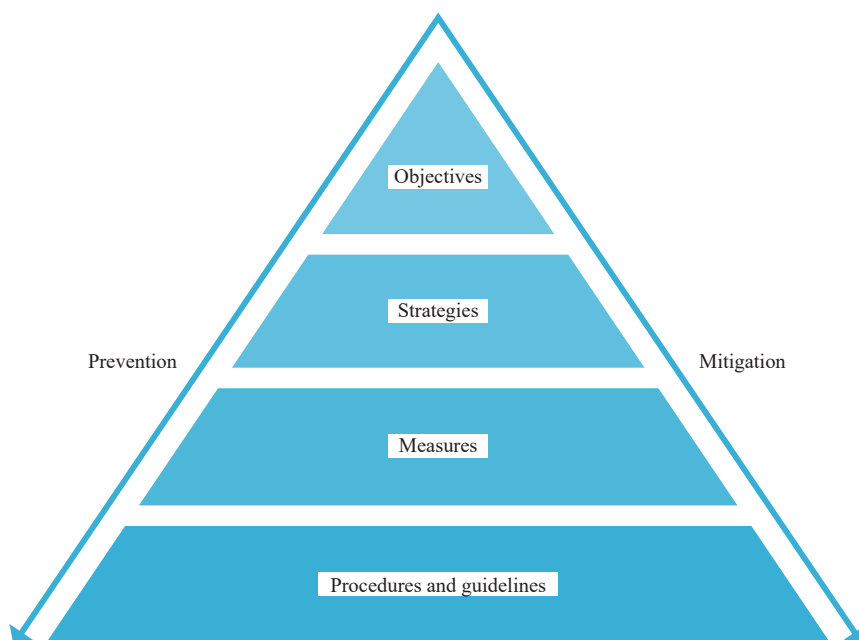


FIG. 1. The structure of accident management guidance: Top-down approach.

- (d) Maintaining the integrity of the containment and preventing containment bypass (strategies for maintaining containment integrity and preventing bypass are of the highest priority once the mitigatory domain is entered);
- (e) Minimizing releases of radioactive substances from the fuel or at other locations where releases of radioactive material could occur;
- (f) Returning the plant to a long term safe stable state in which the fundamental safety functions can be preserved.

2.15. In the preventive domain, strategies⁵ should be developed to preserve the fundamental safety functions that are important to prevent fuel damage or the release of radioactive material either in the reactor or at other locations where fuel is located. In the mitigatory domain, strategies should be developed to avoid any early radioactive release or large radioactive release. Strategies should be developed to delay or minimize any early radioactive release or large radioactive release if those strategies become necessary and are reasonably practicable.

2.16. Accident management strategies should be prioritized with account taken of the plant damage state and the existing and anticipated challenges. The basis for the selection of priorities among accident management strategies should be the following:

- (a) Before significant fuel rod degradation has occurred: Preventing fuel damage is the first priority, and maintaining or restoring the integrity of the containment is the second priority.
- (b) After significant fuel rod degradation has occurred: Maintaining the integrity of the containment is the highest priority.

2.17. When prioritizing accident management strategies, special attention should be paid to the following:

- (a) The time frames and severity of challenges to the barriers against releases of radioactive material.
- (b) The availability of support functions, as well as the possibility of their restoration.
- (c) The initial operating mode of the plant, as accidents can develop in operating modes in which one or more fission product barriers have already been lost at the beginning of the accident.

⁵ An example of a preventive strategy is ‘feed and bleed’ to depressurize the reactor pressure vessel and ensure cooling of the core. Another example is the use of non-permanent equipment during a prolonged station blackout caused by an external hazard.

- (d) The adequacy of a strategy in the given domain; some strategies can be adequate in the preventive domain but not as relevant in the mitigatory domain owing to changing priorities. For example, cooling the fuel could be the first priority when the fuel is undamaged and the containment is intact, while restoring the containment integrity or limiting fission product releases could be the first priority when the containment is open (e.g. at shutdown) or has been damaged (e.g. cracks resulting from very severe mechanical loadings).
- (e) The difficulty of implementing several accident management strategies in parallel.
- (f) The long term implications of or concerns about implementing the accident management strategies.

2.18. If accident management strategies rely on non-permanent equipment after an extended loss of all AC power, steps should be taken to ensure that personnel can install and operate such equipment within the time frame necessary to avoid loss of the fundamental safety functions, taking into account possible adverse conditions on the site. Support items, such as fuel for non-permanent equipment, should be available.

2.19. The implementation of specific accident management strategies should be triggered either when certain parameters reach their threshold values or when trends of significant parameters are observed such that their reaching threshold values is imminent. These parameters should be selected to be indicative of challenges to fission product barriers (see IAEA Safety Standards Series No. SSG-2 (Rev.1), Deterministic Safety Analysis for Nuclear Power Plants [12]).

2.20. When accident management strategies that need to be implemented within a certain time window are considered, the inherent uncertainty in determining accurately the time that has elapsed since the onset of the accident should be taken into account in identifying such a time window. However, care should be exercised not to discard potentially useful strategies.

2.21. From the accident management strategies, suitable and effective measures for accident management should be derived that correspond to available hardware provisions at the plant. Such measures may include plant modifications where these are deemed important for managing accidents. Actions initiated by personnel in the main control room or actions taken at another location are usually an important part of these measures. During an actual accident, such measures would include the use of systems and equipment still available, the recovery of

failed equipment and, potentially, the use of non-permanent equipment⁶ stored on the site or off the site.

2.22. From the accident management strategies, appropriate instructions or guidance, in the form of procedures (EOPs, preferably used to prevent significant fuel rod degradation) and guidelines (SAMGs, preferably used to mitigate the effects of significant fuel rod degradation) should be developed. There are some situations in which procedures are appropriate for mitigation, such as those in which preventive measures need to be continued during mitigation and those in which the procedures are needed to operate or align specific equipment.

2.23. The accident management guidance should assist the operating organization personnel in prioritizing, monitoring and executing actions in the harsh environments that may exist during an accident, including accidents resulting from external hazards that are more severe than external events considered for design.

2.24. The interface with radioactive waste management during accidents should be considered so as to enable access to certain areas in order to perform local accident management actions (see IAEA Safety Standards Series No. GSR Part 5, Predisposal Management of Radioactive Waste [13]).

2.25. Interfaces between safety and security should be managed appropriately throughout the lifetime of the plant, and in all plant states, in such a way that safety measures and security measures do not compromise one another. In particular, nuclear security measures should be maintained as appropriate during all phases of accident management (see Ref. [14]).

MAIN PRINCIPLES

2.26. Accident management guidance should be developed for all reasonably foreseeable mechanisms that could challenge fundamental safety functions or barriers to a release of radioactive material.

2.27. Accident management guidance should be an integral part of the overall emergency arrangements and should be coordinated with the on-site emergency plan, established in accordance with GSR Part 7 [7], GSG-2 [8] and

⁶ 'Non-permanent equipment' is portable or mobile equipment that is not permanently connected to the plant and is stored in an on-site or an off-site location.

GS-G-2.1 [9]. The on-site emergency plan should set out the lines of responsibility and accountability for implementing emergency response actions during the execution of accident management guidance to maintain or restore safety functions throughout the duration of the accident.

2.28. Accident management guidance should be robust:

- (a) It should promote consistent implementation by all staff during an accident.
- (b) It should emphasize the use of components and systems that are not likely to fail in their expected operating regimes, including during severe accidents.
- (c) It should implement all feasible measures that will either maintain or increase the margin to failure or that will gain time before the failure of safety functions or of barriers to a release of radioactive material.
- (d) It should address the possibility of adding components, including non-permanent equipment, in the event that existing plant systems are unable to preserve the fundamental safety functions or limit challenges to barriers to a release of radioactive material for conditions not considered in the design.
- (e) It should consider plant conditions in shutdown modes, particularly when the containment barrier is temporarily not available or when it is difficult to add water for decay heat removal.

2.29. The accident management guidance should refer to the preferred accident management equipment that is available. Possible equipment failures (e.g. instrumentation failure or equipment lockout) should be considered. Alternate methods of achieving the same purpose should be explored to take into account possible equipment failures, and the availability of alternative equipment should be determined.

2.30. In the accident management guidance, the entry conditions for use of the EOPs and the plant conditions under which the transition is to be made from EOPs to SAMGs should be specified. The entry conditions for the use of EOPs and the conditions for transition to SAMGs should be based on defined and documented criteria.

2.31. The accident management guidance should address the full spectrum of events, including credible and relevant internal and external hazards, and possible complications during their evolution that could be caused by additional hardware failures or human and organizational errors. Accident sequences involving inappropriate operator actions (errors of omission or errors of commission) leading to core damage should be considered.

2.32. Accident management guidance relating to human and organizational factors should include consideration of the following:

- (a) The performance of personnel under the contextual and adverse boundary conditions given;
- (b) The command and control structure, including information sharing and cooperation among the staff involved.

2.33. The operating organization should have full responsibility for the implementation of the accident management guidance and should take steps to ensure that the roles of the different members of the on-site emergency response organization involved in accident management have been clearly defined, allocated and coordinated.

2.34. Adequate staffing and working conditions (e.g. acceptable levels of radiation, temperature, humidity and lighting, as well as acceptable access to the plant from off the site) should be considered for accident management, including conditions resulting from external hazards more severe than those considered for the design, derived from the site hazard evaluation. Contingency plans should be prepared to ensure that alternate personnel are available to fill the corresponding positions if certain staff are unavailable.

2.35. Guidance for the assessment of damage to the plant should be part of the accident management programme and should be developed to address challenges to the fundamental safety functions or the fission product barriers before any significant fission product release. Of particular importance is the assessment of access to the site and structural damage to buildings resulting from external hazards more severe than those considered for design, derived from the site hazard evaluation.

2.36. In accordance with para. 5.8C of SSR-2/2 (Rev. 1) [6], contingency measures — such as compressed air or other gases, mobile electrical power sources and alternative supplies of water — are required to be located and maintained so as to be functional and readily accessible when they are needed.

2.37. Accident management guidance should be considered for any specific challenges posed by shutdown plant configurations and large scale maintenance. The potential for damage to fuel in the reactor core and in the spent fuel pool, and in on-site dry storage if applicable, should also be considered in the accident management guidance. As large scale maintenance is frequently carried out

during planned shutdown states, the protection of workers should be a high priority of accident management.

2.38. Accident management guidance should be, as far as feasible, based on either directly measurable plant parameters or information derived from simple calculations and should consider the possible loss or unreliability of indications of essential plant parameters for equipment that has not been designed to withstand such accident conditions.

2.39. The set of accident management guidance, including procedures and guidelines, should include design limits and/or relevant plant parameters that should be monitored, and these limits and parameters should be referenced or linked to the criteria for the initiation, throttling or termination of the various systems. The time needed to obtain adequate information important for accident management should be taken into account when developing accident management guidance.

2.40. Specific attention should be paid to situations in which instrumentation is lost or incorrect owing to a loss of power or a harsh environment. Arrangements should be established for making adequately informed decisions in such cases. If measurements are not available, parameters should be estimated by means of simple computations (e.g. using steam tables) or precalculated graphs.

2.41. The accident management guidance should be efficient for actions that are subject to time constraints (e.g. the depressurization of the reactor coolant system; the isolation or venting of the containment).

FORMS OF ACCIDENT MANAGEMENT GUIDANCE

Accident management guidance in the preventive domain (before significant fuel rod degradation)

2.42. For accidents without significant fuel rod degradation, the accident management guidance should take the form of procedures, usually called EOPs, that are prescriptive in nature. EOPs also typically address design basis accidents.⁷ EOPs may be complemented by other guidance when necessary.

⁷ EOPs are also used in the mitigatory domain in some plants, especially in the early phase of a severe accident, for actions initiated from the main control room before the technical support centre is functional.

The figure in the Appendix shows the relationship between the type of accident management guidance used, the fuel rod status and the plant state.

2.43. Further details on the objective, scope, development and implementation of EOPs are given in IAEA Safety Standards Series No. NS-G-2.2, Operational Limits and Conditions and Operating Procedures for Nuclear Power Plants [15], and in Ref. [16].

Accident management guidance in the mitigatory domain (when significant fuel rod degradation is imminent or ongoing)

2.44. When significant fuel rod degradation is imminent or ongoing, large uncertainties may exist in the plant status, in the availability of the systems and in the timing and outcome of actions. Consequently, the guidance for mitigating significant fuel rod degradation, usually called SAMGs, should distinguish between what can be prescriptive in nature (because there is no doubt as to the benefit of the prescribed actions, for example depressurization of the reactor coolant system for pressurized water reactors) and what cannot be prescriptive in nature. In the latter case, the guidance should include a range of possible mitigatory actions and should allow for additional evaluation and alternative actions.

2.45. The guidance for mitigating significant fuel rod degradation should contain a description of the positive and negative potential consequences of the proposed actions, including quantitative data when available and relevant; should be simple, clear and unambiguous; and should contain sufficient information for the plant staff and the staff of support organizations to reach a timely decision on the actions to take during the evolution of a severe accident.

2.46. The guidance for mitigating significant fuel rod degradation should be presented in an appropriate form, such as guidelines, manuals, handbooks or procedures. In this Safety Guide, the term ‘guideline’ is used to describe a set of strategies and measures that describe the tasks to be executed at the plant but which are still less strict and prescriptive than the procedures found in the EOPs. Manuals or handbooks typically contain a more general description of the tasks to be executed and the justifications for use of those tasks.

2.47. SAMGs should be developed with an appropriate level of detail and in a format that facilitates their effective use under stressful conditions. The form of the SAMGs (i.e. whether they set out step-by-step instructions or are intended to

guide flexible decisions) should be considered in the development process and should be clear to the users.

2.48. The overall form of the guidelines and the selected level of detail should be evaluated during validation of the guidelines and then tested in exercises. On the basis of such exercises, it should be judged whether the form is appropriate and whether additional detail should be included in the SAMGs. Exercises should enable identification of areas for improvement.

Development of accident management guidance for both the preventive and mitigatory domains

2.49. Accident management guidance should be written in a predefined format using simple and consistent language and specific terms in accordance with established rules; such rules should preferably be established in a writers' guide.

2.50. The team developing accident management guidance, such as the plant vendor or designer, should consider the potential loss of the command and control structure due to damaged infrastructure (e.g. from an external hazard more severe than those considered for the design, derived from the site hazard evaluation) and should develop associated guidance that takes account of the following:

- (a) The number of affected units (the reactor core and spent fuel pools);
- (b) The functionality and habitability of control facilities;
- (c) Damage to essential structures and buildings;
- (d) The availability of AC and DC power required for the operation of plant systems;
- (e) Access to essential buildings and equipment;
- (f) The availability of operating personnel and site staff for implementation of procedures and guidelines;
- (g) Whether actions can be taken by non-licensed personnel, typically an auxiliary operator;
- (h) The availability of other on-site control rooms and personnel in separate buildings;
- (i) The capability of communicating within the plant emergency command and control structure and with off-site organizations.

2.51. In some situations the arrangements for directing the response might be unavailable owing to, for example, loss of the command and control structure due to loss of the main control room or impairment of the capability to set up the on-site emergency response organization. Supporting procedures or guidelines