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Severe Accident Management Programmes for Nuclear Power Plants

DRAFT SPECIFIC SAFETY GUIDE (DS483)

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1. INTRODUCTION

BACKGROUND

1.1. This Safety Guide was prepared under the IAEA's programme for establishing safety standards. It revises and supersedes the Safety Guide on Severe Accident Management Programmes for Nuclear Power Plants issued in 2009[1], and is aimed at providing 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. Accident management is the taking of a set of actions in the plant during the evolution of an accident with the objective of preventing the escalation of the event into a severe accident and mitigating the consequences of a severe accident should it occur, and achieving a long term safe and stable state[2]. The second aspect of accident management, namely mitigating the consequences of a severe accident, is also termed severe accident management. The return of the plant to the long term safe stable state is also called accident recovery.

1.3. Accident management is an essential component of the application of defence in depth to prevent or mitigate the consequences of a severe accident [1– 4].

1.4. A severe accident management programme comprises the preparatory measures, procedures and guidelines, equipment and human resources for preventing the progression of accidents, including severe accidents which are beyond design basis accidents, and for mitigating their consequences if they do occur [5].

1.5. Two different types of operating guidance documents for accident management are used, referred to as emergency operating procedures (EOPs) for preventing fuel degradation and severe accident management guidelines (SAMGs) for guiding the Technical Support Centre (or equivalent) or crisis teams and the main control room during severe accidents.

1.6. Depending on the plant state, accident management actions are prioritized as follows:

(1) Before the onset of fuel degradation, priority is given to preventing the escalation of

[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 and 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 and maintained stable for a long time.

the accident into a severe accident (preventive domain of accident management). In this domain, actions are implemented to stop the accident progressing to the onset of fuel degradation, or to delay the time at which significant fuel degradation happens and to secure all of the main safety functions.

(2) When plant conditions indicate that significant fuel degradation is imminent or in progress, priority is given to mitigating the consequences of the severe accident (mitigatory domain of accident management) through:

- Maintaining the integrity of the remaining fission product barriers which depending upon the design can include the reactor pressure vessel[3] and the containment;
- Performing any other actions to avoid or limit fission product releases to the environment and releases of radionuclides causing off-site contamination including the return to the extent possible to a condition in which the main safety functions are secured.

Characteristics of the preventive and mitigatory domains of accident management are summarized in Table 1.

1.7. (Severe?) Accident management programme encompasses plans and actions undertaken to ensure that the plant and the personnel with responsibilities for accident management are adequately prepared to take effective on-site actions. The severe accident management programme needs to be well integrated with the arrangements for emergency preparedness and response established in accordance with Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSR Part 7 [6], Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSG-2 [7] and Arrangements for Preparedness for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GS-G-2.1 [8], for example, in terms of human resources, equipment, strategy and procedures.

1.8. The severe accident management programme needs to cover all initial modes of operation before the accident, including combinations of events and failures that could cause a loss of fuel integrity and ultimately significant radioactive releases to the environment.

1.9. The severe accident management programme needs to involve the establishment of

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

the necessary infrastructure to effectively prevent or mitigate the consequences of a severe accident, prevent fuel degradation, and achieve a long term safe stable state if fuel degradation does occur.

OBJECTIVE

1.10. This Safety Guide presents recommendations for the development and implementation of a severe accident management programme for meeting the requirements for accident management that are established in Sections 3 and 5 of Safety of Nuclear Power Plants: Operation and Commissioning, IAEA Safety Standards Series No. SSR-2/2 (Rev. 1) [5], in Sections 2 and Section 5 of Safety of Nuclear Power Plants: Design, IAEA Safety Standards Series No. SSR-2/1 (Rev. 1) [2], in Section 4 in Safety Assessment for Facilities and Activities, IAEA Safety Standards Series No. GSR Part 4 (Rev. 1) [9] and in Requirement 8 of GSR Part 7 [6].

1.11. 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 reviews and safety assessments.

SCOPE

1.12. This Safety Guide provides recommendations for the development and implementation of a severe 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 regarding the design of structures, systems and components to address design extension conditions. For information on this topic refer to Section 5 of SSR-2/1 (Rev. 1) [2].

1.13. This Safety Guide provides recommendations relating to a severe accident management programme on the site and does not include consideration of all aspects of emergency preparedness and response, which is addressed in GSR Part 7 [6].

1.14. Although the recommendations of this Safety Guide have been developed primarily for use for 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 storage of spent nuclear fuel).

STRUCTURE

1.15. This Safety Guide consists of four sections and one annex. Section 2 presents the general recommendations for a severe accident management programme. More detailed, specific recommendations for the process of development and implementation of a severe accident management programme are provided in Section 3. Recommendations on the execution of SAMGs are described in Section 4. Examples of the implementation of SAMGs in different States are provided in the Annex.

Table 1: Characteristics of the preventive and mitigatory domains of accident management

	Preventive domain (prevention of progress to a severe accident)	Mitigatory domain (mitigation of the consequences of a severe accident)
Objective	Prevention of fuel damage fulfilment of the fundamental safety functions.	Limitation of releases of radioactive material to the environment through actions comprising maintenance of the integrity of the containment, prevention of containment bypass and control of releases termination of progression of core melt or fuel melt, maintenance of the integrity of the reactor pressure vessel, , and emergency response measures for minimizing radiological consequences.
Establishment of priorities	Establishment of priorities among the various fundamental safety functions.	Establishment of priorities between mitigatory measures, with the highest priority given to mitigation of significant ongoing releases and immediate threats to fission product barriers.
Responsibilities (authorization of actions)	Main control room staff or emergency director, if deemed appropriate.	On-site emergency director (or equivalent).
Role of relevant emergency response organization	Technical support centre available to provide advice to main control room, or to make decisions for complex tasks, if deemed appropriate.	Technical support centre (or other emergency response facility) responsible for evaluation and recommendation of actions or for making recommendations to decision makers for complex tasks to be carried out by the main control room, if deemed appropriate.

Procedures/guidelines	Use of procedures for preventive accident management measures (EOPs) by staff in the main control room.	Use of SAMGs by staff of the technical support centre or other designated organization.
Use of equipment	Use of all systems available and non-permanent equipment (e.g. mobile or portable); also use of equipment beyond its originally intended function may be admissible; advice or instructions are provided by EOPs and staff of the technical support centre[4].	Use of all systems still available and alternatives (i.e. non-permanent equipment) to fulfil the fundamental safety functions; systems may also be used beyond their design limits if available and appropriate.
Verification of effectiveness	The effectiveness of the accident management measures should be verified and validated with reasonable accuracy.	The effectiveness of the accident management measures should be verified and validated as far as reasonably possible. Positive and negative consequences of proposed actions should be considered in advance and monitored throughout and after implementation of the actions, unless such actions are to prevent or mitigate a severe challenge to containment integrity and immediate action is required in accordance with the SAMGs.

[4] In some States, decisions can be taken only by a particular authorized person (e.g. the 'accident management chief'), while other individuals provide information and advice to this person.

2. GENERAL GUIDANCE FOR A SEVERE 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) [5] requires that "the operating organization shall establish, and shall periodically review and as necessary revise an accident management programme".

2.2. Paragraph 2.10 on safety in design in SSR-2/1 (Rev. 1) [2] states that:

> "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."

2.3. Paragraph 5.6 in GSR Part 4 (Rev. 1) [9] requires that "the results of the safety assessment shall be used as an input into planning for on-site and off-site emergency response and accident management".

2.4. Paragraph 5.25 in GSR Part 7 [6] requires that:

> "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".

2.5. Paragraph 5.25 in GSR Part 7 [6] further requires that:

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

CONCEPT OF A SEVERE ACCIDENT MANAGEMENT PROGRAMME

2.6. A severe accident management programme should be developed and implemented for the prevention and mitigation of severe accidents, irrespective of the core damage frequency and fission product release frequency considered in the design.

2.7. The severe accident management programme should be developed and maintained consistent with the plant design and its current configuration. The severe accident management programme should be periodically reviewed and revised where appropriate to reflect the changes of plant configuration, operating experience, including major lessons identified, and new results from relevant research.

2.8. The severe 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. It should also consider extreme external hazards[5] that could result in significant damage to the infrastructure on the site or off the site.

2.9. For a multi-unit nuclear power plant site on which several units are co-located, the severe accident management programme should consider concurrent severe accidents on multiple units.

2.10. A structured top-down approach should be used to develop the accident management guidance. This approach should begin with the objectives and strategies followed by measures to implement the strategies and finally result in procedures and guidelines, and should cover both the preventive and the mitigatory domains. Figure 1 illustrates the top down approach to accident management.

[5] Extreme external hazards are external hazards of a level more severe than those considered for the design, derived from the site hazard evaluation.

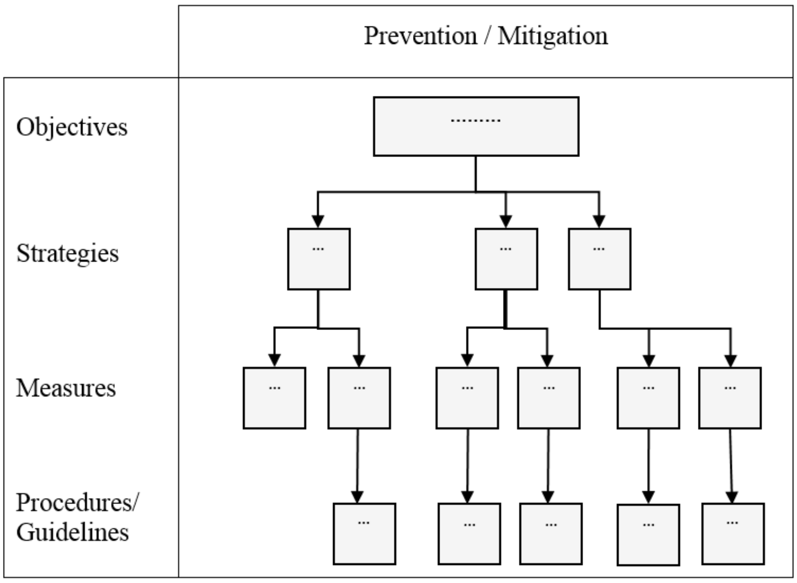

FIG. 1 The structure of accident management guidance by use of the top-down approach

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

- Preventing or delaying the occurrence of fuel degradation;
- Terminating the progress of fuel degradation once it has started;
- Maintaining the integrity of the reactor pressure vessel to prevent melt-through especially at high pressure;
- Maintaining the integrity of the containment and preventing containment bypass (strategies for the maintaining containment integrity and preventing bypass are of the highest priority once the mitigatory domain is entered);
- Minimizing releases of radioactive material from the fuel or at other locations where releases of radioactive material could occur;
- Returning the plant to a long term safe stable state in which the fundamental safety functions can be preserved.

2.12. From the 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, including severe accidents. Actions initiated by personnel in the main control room or actions taken at another location could be an important part of these measures. During an accident such measures would include the use of systems and equipment still available, the recovery of failed equipment and the use of non-permanent equipment[6], stored on the site or off the site.

2.13. From the strategies and measures, appropriate guidance, in the form of procedures (called emergency operating procedures (EOPs,) and preferably used in the preventive domain of accident management) and guidelines (called severe accident management guidelines (SAMGs), preferably used in the mitigatory domain of accident management), should be developed

2.14. Accident management guidance should assist plant 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 the design.

2.15. When developing guidance on accident management, consideration should be given to the full capabilities of the plant, using installed and non-permanent equipment as appropriate. Particular care should be taken if the possible use of some systems beyond their originally intended function is foreseen in the accident management guidance.

2.16. Specific consideration should also be given to maintaining the conditions necessary for the continued operation of equipment that is ultimately necessary to prevent large or early radioactive releases.

2.17. The interface with radioactive waste management for intermediate remediation of contaminated areas during and/or after accidents should be considered, so as to enable access certain areas in order to perform local accident management actions (see IAEA Safety Standards Series No. GSR Part 5, Predisposal Management of Radioactive Waste [10].

2.18. 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.[11]).

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[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.

MAIN PRINCIPLES

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

2.20. 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 [6], GSG-2 [7] and GS-G-2.1 [8]. 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.

2.21. Accident management guidance should be robust, which can be ensured by the following:

(1) It should promote consistent implementation by all staff during an accident.

(2) It should emphasize the use of components and systems that are not likely to fail in their expected operating regimes, including during severe accidents.

(3) It should implement all feasible measures that will either maintain or increase the margin to failure or that will gain time prior to the failure of safety functions or barriers to a release of radioactive material.

(4) The possibility of adding components, including non-permanent equipment, should be addressed in the accident management guidance 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.

(5) It should include consideration of plant conditions in shutdown modes, particularly when the containment barrier is temporarily not available or it is difficult to add water for decay heat removal.

2.22. In the accident management guidance, the plant conditions at which the transition is to be made from the preventive domain to the mitigatory domain should be specified and should be based on defined and documented criteria.

2.23. 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 and human errors.

2.24. External hazards should be considered with a level of severity exceeding the magnitude established in the site evaluation and/or its equivalent and with a mean annual frequency exceeding the probability of accidents established in the design for the plant[7] (see IAEA Safety Standards Series No. NS-R-3 (Rev. 1), Site Evaluation for Nuclear Installations [12]).

2.25. Accident management guidance should also consider that, in the case of extreme external hazards, there may be extensive infrastructure damage, so that off-site resources are not readily available; examples of such off-site resources include human resources and/or means of communication, electrical power supplies, means of transport and availability of spare parts, lubricants, compressed air, water and fuel.

2.26. Contingency measures, such as alternative supplies of water, compressed air or other gases and mobile electrical power sources, should be located and maintained so as to be functional and readily accessible when they are needed.

2.27. 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 both 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, a high priority of the management of the accident should be the protection of workers.

2.28. Accident management guidance should include the equipment and supporting procedures necessary to respond to accidents that may affect multiple units on the same site and last for extended periods of time. Personnel should have adequate skills for using such equipment and implementing supporting procedures, and adequate staffing plans should be developed for emergency response on sites with multiple units.

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

2.30. Adequate staffing and working conditions (e.g. acceptable radiation levels, temperatures and humidity and lighting and access to the plant from off the site) should be

[7] For example, in some States a mean annual frequency is considered that is at least one order of magnitude greater than the probability of accidents considered in the design.

considered for accident management, including those resulting from extreme external hazards. Some events may result in similar challenges to all units on the site. Therefore staffing plans should take into account situations where multiple units on the same site have been affected simultaneously and some plant personnel have been temporarily or permanently incapacitated. Contingency plans should be prepared to ensure that alternate personnel are available to fill the corresponding positions in the case of unavailability of staff.

2.31. Preferably, the accident management guidance should be set out in such a way that it is not necessary for the responsible staff to identify the accident sequence or to follow some pre-analysed accidents in order to be able to execute the accident management guidance correctly.

2.32. The development of accident management guidance should be supported by best estimate analysis of the physical response of the plant. In the accident management guidance, consideration should be given to uncertainties in knowledge about the timing and magnitude of phenomena that might occur in the progression of the accident. Hence, accident management actions should be initiated at the level of parameters and at a time that gives sufficient confidence that the goal intended to be achieved by carrying out the action will be reached.

2.33. The 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 against such accidents conditions.

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

EQUIPMENT UPGRADES

2.35. Items important to safety for the prevention or mitigation of accidents should be identified and evaluated. Accordingly, existing equipment and/or instrumentation should be upgraded or new equipment and/or instrumentation should be added, if necessary or beneficial for improving the plant's safety through a severe accident management programme.

2.36. When the addition or upgrade of existing equipment or instrumentation is considered, related design requirements should be such that there is reasonable assurance[8] that this equipment or instrumentation will operate as intended in an accident, including accidents originated by extreme external hazards. The operability of the considered equipment or instrumentation should be demonstrated either by equipment qualification or by assessment of the survivability of the equipment or instrumentation.

2.37. Where existing equipment or instrumentation is upgraded or otherwise to be used outside its previously considered design basis range, the accident management guidance for the use of such equipment should be updated accordingly.

2.38. New equipment should be designed against accident conditions and for conditions arising from internal and external hazards commensurate with the intended function.

2.39. Equipment, either permanent equipment, or non-permanent equipment that is stored on the site or off the site, should be protected against postulated hazardous conditions including internal and external hazards that cause the challenge. For non-permanent equipment, such as portable or mobile equipment, it should be verified that the equipment can be moved from its storage location to the location where it fulfils its accident management function and that the necessary connections can be established under the conditions existing during the accident and within the necessary time frame.

2.40. The impact of new or upgraded equipment on the staffing needs, as well as expectations for maintenance and testing, should be addressed.

2.41. The installation of new equipment or the upgrading of existing equipment to operate under harsh environmental conditions is not sufficient to eliminate the need for development of accident management guidance for situations in which some of this equipment malfunctions.

FORMS OF ACCIDENT MANAGEMENT GUIDANCE

Preventive domain

2.42. In the preventive domain, the guidance should take the form of procedures, usually called EOPs, that are prescriptive in nature. EOPs should address all accidents without significant fuel degradation.

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[8] Reasonable assurance that there exists a quantifiable positive margin to equipment failure can be obtained through evaluation based on available information coming from different sources.

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 [13] and Ref. [14].

Mitigatory domain

2.44. In the mitigatory domain, 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 the mitigatory domain, 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 the mitigatory domain should contain a description of both the positive and negative potential consequences of proposed actions, including quantitative data, where available and relevant, and should be simple, clear and unambiguous and 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 the accident.

2.46. The guidance for the mitigatory domain should be presented in an appropriate form, such as guidelines, manuals or handbooks. The term ‘guideline’ here 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, i.e. the guidance used in the preventive domain. Manuals or handbooks typically contain a more general description of the tasks to be executed and their justification.

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 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. Based on the outcome 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.

Both preventive and mitigatory domains

2.49. For situations that result in the arrangements for directing the response being unavailable, such as 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 may be developed on the use of instrumentation and equipment to cope with such conditions. The accident management guidance should include conditions for use of such supporting procedures or guidelines.

2.50. The procedures and guidelines developed for accident management should be supported by appropriate background documentation (this is sometimes referred to as the technical basis document). This documentation should describe and explain the rationale of the various parts of the SAMGs, including a full description of the benefits and potential negative implications, and should include an explanation of each individual step, if necessary. The background documentation does not replace the SAMGs themselves. It should be made available to all staff involved in evaluation and decision making.

2.51. The background documentation should be used to support training of the staff of the technical support centre on the phenomenology of severe accidents, the basis for SAMGs and the benefits and detriments of various postulated mitigatory actions.

2.52. Hardcopies of the EOPs and SAMGs should always be available in all evaluation and decision making locations, such as the main control room, the supplementary control room and the technical support centre, so that they can be used as necessary, in particular in case of station blackout. Hardcopies should also be made available in all locations used as backups in case of accidents caused by extreme external hazards.

ROLES AND RESPONSIBILITIES

2.53. The decision making authority should be clearly defined and established at an appropriate level, commensurate with the complexity of the task and the potential consequences of decisions to be made. In the preventive domain, the main control room supervisor or a dedicated safety engineer or other designated official should fulfil this responsibility. In the mitigatory domain, decisions should be made by a person having a broader perspective of all the measures for accident management and a comprehensive understanding of the implications of the decisions. Some States require that the main control room supervisor be capable of performing actions in all aspects of accident management until the person authorized to manage the emergency starts to execute his or her duties.

2.54. Major decisions that could have significant adverse effects on public safety or the environment should be made with the full knowledge of the person (or persons) who has been assigned legal responsibility for safety at the plant where practicable.

2.55. The accident management guidance should be compatible with the assignment of responsibilities and should be consistent with the other functions considered in the overall emergency arrangements on the site and off the site, if appropriate.

2.56. The roles assigned to the members of the emergency response organization may be different in the preventive and mitigatory domains, and, where this is the case, transitions of responsibility and authority should be clearly defined.

2.57. A specialized team or group of teams (referred to in the following as the technical support centre staff) should be available in an emergency to provide technical support to the operating personnel. The staff of the technical support centre should have the capability, based on their knowledge of the plant status, of recommending mitigatory actions as deemed most appropriate for the situation. This should be done only after evaluation of the potential consequences of such recommended actions and the possibility and consequences of using erroneous information. If the staffs of the technical support centre are composed of multiple teams, the role of each team should be specified.

2.58. Appropriate levels of training should be provided to members of the staff responsible for accident management; the training should be commensurate with their responsibilities in the preventive and mitigatory domains, as well as their responsibilities in deciding when to transition from the preventive domain to the mitigatory domain.

3. DEVELOPMENT AND IMPLEMENTATION OF A SEVERE ACCIDENT MANAGEMENT PROGRAMME

TECHNICAL BASES

3.1. Six main steps should be executed to set up and develop a severe accident management programme:

(1) Identification of challenge mechanisms:

- Mechanisms that could challenge the fundamental safety functions or the barriers to a release of radioactive material should be identified.

(2) Identification of plant vulnerabilities:

- Plant vulnerabilities should be identified, considering the challenge mechanisms, including the concurrent loss of the fundamental safety functions.

(3) Identification of plant capabilities:

- For challenges to the fundamental safety functions and fission product barriers, the plant capabilities, including capabilities to mitigate such challenges, in terms of both available equipment and available personnel, should be considered.
- The available or necessary hardware provisions for the execution of accident management strategies should be considered.

(4) Development of accident management guidance:

- Suitable accident management guidance should be developed, including the use of permanent and on-site and off-site non-permanent equipment and instrumentation to cope with the vulnerabilities identified.
- Development of accident management guidance should be supported by best estimate analyses.
- Dependencies between external hazards should be considered.
- The possibility and consequences of using erroneous information should be considered.
- The means of obtaining information on the plant status, and the role of instrumentation therein should be considered, including cases in which the

information provided by instrumentation is erroneous and all normal power for instrumentation and control systems is unavailable.

- Possible restrictions on the accessibility of certain areas for performing local actions should be considered.
- Suitable procedures and guidelines to execute the strategies and measures should be developed.
- Accident management strategies should consider extremely low probability events

(5) Establishment of a verification and validation process of the severe accident management programme.

(6) Integration of the severe accident management programme into the management system:

- The lines of decision making, responsibility and authority in the teams that will be in charge of the execution of the accident management guidance should be specified.
- Human and organizational factor aspects should be considered using a systemic approach to safety [add reference to GSR Part 2].
- A systematic approach to the periodic evaluation and updating of the guidance and training should be considered, with incorporation of new information and research insights into severe accident phenomena.
- Education and training, exercises and drills and evaluation of personnel skills should be considered.
- Integration of the severe accident management programme with the emergency arrangements for the plant should be ensured.

3.2. Severe accident sequences should be identified and analysed, using a combination of engineering judgement and deterministic methods and probabilistic methods. Sequences for which practicable accident management guidance can be implemented should be identified. Acceptable accident management guidance should be based upon best estimate assumptions, methods and analytical criteria. Activities for developing accident management guidance should take into account the following:

(a) Operating experience, relevant safety analysis and results from safety research;

(b) Review of these accident sequences against a set of criteria aimed at determining which severe accident challenges should be addressed in the design of the severe accident management programme;

(c) Evaluation of potential design or procedural changes that could either reduce the likelihood of occurrence of these selected challenges or mitigate their consequences, and decisions on the implementation of such changes;

(d) Consideration of plant design capabilities, including the possible use of;

- Systems beyond their originally intended function and anticipated operational states, when the use of such systems will not exacerbate the situation;
- Additional non-permanent systems or components, to return the plant to a long term safe stable state and/or to mitigate the consequences of a severe accident, provided that it can be shown that the systems are able to function in the environmental conditions to be expected;

(e) For multiple unit sites, consideration of the use of available means and/or support from other units on the site, provided that the safe operation of those units is not compromised.

IDENTIFICATION OF CHALLENGE MECHANISMS

3.3. The selection of severe accident sequences should be sufficiently comprehensive to provide a basis for the development of accident management guidance for plant personnel and support personnel in any identified situation. Level 1 and Level 2 probabilistic safety assessment (PSA) (see IAEA Safety Standards Series No. SSG-3, Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants [15] and IAEA Safety Standards Series No. SSG-4, Development and Application of Level 2 Probabilistic Safety Assessment for Nuclear Power Plants [16]), engineering judgement or similar studies from other plants, and operating experience at the plant or at other plants can provide a basis for the selection of severe accident sequences.

3.4. (Severe?) Accident management programme should address the full spectrum of challenges to fission product barriers, including those arising from multiple hardware failures, human errors and postulated hazardous conditions, including extreme external hazards, and possible consequential failures and physical phenomena that may occur during the evolution of a severe accident. In the development process of SAMGs, even highly improbable failures should be considered.

3.5. For determination of the full spectrum of challenge mechanisms to fission product barriers, useful input can be obtained from the Level 2 PSA for the plant, or similar studies from other plants, engineering judgement and insights from research on severe accidents. However, the identification of potential challenge mechanisms should be comprehensive to the extent possible to provide a basis for the development of accident management guidance for plant personnel in all situations, even if the evolution of the accident would constitute a very unlikely path within the Level 2 PSA or is not identified in the Level 2 PSA at all.

3.6. In view of the inherent uncertainties involved in determining credible events, the PSA for the plant should not be used a priori to exclude accident sequences from consideration in the development of accident management guidance. If such an approach is considered, extremely low cut-off levels should be specified so as not to underestimate the scope and nature of the accident sequences to be analysed.

3.7. Accident management guidance may be developed first on a generic basis by the plant vendor or plant designer or by other organization duly authorized by the operating organization, and may then be used by the operating organization for development of a plant specific severe accident management programme. Accident management guidance may also be developed on a plant specific basis without the use of generic documentation. When adapting generic accident management guidance to plant specific conditions, care should be taken that the transition condition from preventive domain to mitigatory domain is handled appropriately, including searching for additional vulnerabilities and strategies to mitigate these. Any deviations from plant operating requirements and generic accident management guidance should be subject to rigorous review that considers the basis for and benefits of the original approach and the potential unintended consequences of deviating from this approach.

3.8. To ensure the success of the development of the severe accident management programme, a development team of experts with sufficient scope and level of expertise including all necessary technical disciplines should be involved, with support from the senior management of the operating organization.

IDENTIFICATION OF PLANT VULNERABILITIES

3.9. Guidance for the assessment of damage to the plant should be part of the severe accident management programme, and developed to address challenges to fission product barriers and the fundamental safety functions before any significant fission product release. Of particular importance is the assessment of access to the site and structural damage to buildings resulting from extreme external hazards.

3.10. The vulnerabilities of the plant to challenging conditions should be identified. It should be investigated how specific severe accidents will challenge the fundamental safety functions, and, if these are lost and not restored in due time, how the integrity of the fission product barriers will be challenged.

3.11. The vulnerabilities to postulated hazardous conditions, including extreme external hazards that can impact the use of safety features for accident management, both permanently installed equipment and non-permanent equipment, should be identified. It should be investigated how specific hazards can interfere with the use of safety features for accident management.

3.12. Vulnerabilities resulting from the failure 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 should also be addressed.

3.13. The behaviour of the plant during severe accidents, including severe accidents caused by internal and external hazards, should be well understood, including the identification of the phenomena that may occur, together with their expected timing. The timing of an actual accident is, in general, different from that expected by analytical results and depends on actual plant conditions and the timing of real events, and decision makers should be cognizant of these differences. A symptom-based approach to accident management guidance should be preferred so that decision makers can respond to actual plant conditions and not make decisions solely based on stylized analytical results.

IDENTIFICATION OF PLANT CAPABILITIES

3.14. All plant capabilities available to fulfil and support the plant's safety functions should be identified and characterized. This should include the review of on-site consumable resources for the plant that would be required to support safety systems, as well as the use of non-dedicated systems, and unconventional or alternative line-ups or hook-up connections for non-permanent equipment located on the site or brought in from off the site.

3.15. When unconventional or alternative line-ups or hook-up connections are necessary, consideration should be given to the availability of the equipment necessary to facilitate the establishment of such connections by the appropriate staff and to possible restrictions of authorized access to such equipment.

3.16. To minimize the time needed to deploy equipment in unconventional ways following a severe accident, and to ensure that these actions can be taken with due regard for the safety of the operators involved, the relevant instructions should be prepared in advance, by defining a set of steps that have been appropriately reviewed including identifying the pre-requisites necessary (e.g. pre-staging of any special tools or components) to take actions safely and effectively.

3.17. The ability of plant personnel to successfully perform unconventional measures to mitigate accident challenges under adverse environmental conditions should be carefully considered. Where necessary, personal protective equipment should be provided for the execution of such tasks, for instance protective clothing and breathing equipment. Personnel may need to conduct the assigned tasks in hazardous conditions and procedures and instructions associated with such actions and with radiation protection of staff should be developed (see SSR-2/1 (Rev. 1) [2], GSR Part 7 [6] and IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radioactive Sources: International Basic Safety Standards [17]).

3.18. In determining the capabilities of the plant personnel to deploy mitigating equipment in possible harsh environments, the implications of the following should be considered:

- Working in high temperature, high pressure or high humidity areas;
- Working in poorly lit or dark areas;
- Working in areas ventilated using portable ventilation systems;
- Working in high radiation areas;
- The use of non-permanent instrumentation or non-permanent power supplies.

DEVELOPMENT OF ACCIDENT MANAGEMENT GUIDANCE

Accident management strategies

3.19. On the basis of the vulnerability assessment and identified plant capabilities, as well as the understanding of accident phenomena, accident management strategies should be developed for each individual challenge or plant vulnerability.

3.20. In the preventive domain, strategies[9] should be developed to preserve fundamental safety functions that are important to prevent fuel damage or release of radioactive material either in the reactor or at other locations where fuel is located.

[9] An example of a preventive strategy is ‘feed and bleed’ to depressurize the reactor pressure vessel. Another example is the use of non-permanent equipment for a prolonged station blackout caused by external hazard.

3.21. In the mitigatory domain strategies should be developed with the following objectives:

- Maintaining the integrity of the containment or any other confinement of fuel and preventing containment bypass;
- Minimizing or delaying any off-site releases of radioactive material;
- Preventing re-criticality in the reactor pressure vessel;
- Terminating the progress of fuel degradation in the reactor core and at other locations where fuel is located, such as the spent fuel pool;
- Maintaining the integrity of the reactor pressure vessel and at other locations where fuel is located, such as the spent fuel pool;
- Returning the plant to a long term safe stable state where the fundamental safety functions can be ensured.

3.22. Accident management strategies may be derived from 'candidate high level actions', such as filling the secondary side of the steam generators to prevent creep rupture of the steam generator tubes, depressurizing the reactor coolant system to prevent high pressure failure of the reactor pressure vessel and direct containment heating, flooding the reactor cavity to prevent or delay vessel failure (or facilitate corium spreading on a large area in case of vessel rupture) and subsequent basemat failure, mitigating the impact of combustible gases and depressurizing the containment to prevent its failure by excess pressure or to prevent basemat failure under elevated containment pressure (see Ref. [18]).

3.23. A systematic evaluation of the possible accident management strategies should be conducted to confirm their feasibility and effectiveness, to determine potential negative impacts, and to prioritize the strategies using appropriate methods. Adverse conditions that may affect the execution of a strategy during the evolution of an accident should be considered. The evaluation should be documented in the relevant background document.

3.24. Particular consideration should be given to accident management strategies that have both positive and negative impacts in order to provide the basis for a decision as to which strategies constitute a proper response for a given plant damage state.

3.25. 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 in severe accident management strategies should be the following:

- Preventing fuel damage as the first priority, and maintaining or restoring the integrity of the containment as the second priority before reaching the entry conditions to the mitigatory domain;

- Maintaining the integrity of the containment as highest priority after reaching the entry conditions to the mitigatory domain.

3.26. When prioritizing, special attention should be paid to the following:

- The timeframes and severity of challenges to the barriers against releases of radioactive material.
- The availability of support functions, as well as the possibility of their restoration.
- The initial operating mode of the plant, as accidents can develop in operating modes where one or more fission product barriers could already be lost at the beginning of the accident.
- 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 due 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 first priority when the containment is open (e.g. at shutdown) or has been damaged (e.g. cracks resulting from very severe mechanical loadings).
- The difficulty of developing several accident management strategies in parallel.
- Long term implications of or concerns about implementing the accident management strategies.

3.27. For accident management strategies that rely on non-permanent equipment following 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.

3.28. Severe accident management strategies should also be developed for situations when DC power is lost after a long term loss of all AC power.

3.29. The implementation of specific accident management strategies should be triggered either when certain parameters reach their threshold values or trends of significant parameters are observed such that their reaching threshold values is imminent. These parameters should be selected to be indicative of challenges[10] to fission product barriers.

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[10] Examples of such challenges include: large release at the onset of an accident; bypass of the containment; high pressure melt ejection; melt-through of the core cooling system, loss of the ultimate heat sink and the reactor pressure vessel; combustible gas production and combustion; molten core concrete interaction;

3.30. If accident management strategies are considered that need to be implemented within a certain time window, 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 in order not to discard potentially useful strategies.

3.31. The plant control and logic interlocks that may need to be defeated or reset for the successful implementation of accident management strategies should be systematically identified. It should also be verified that the potential negative effects of such actions have been adequately characterized and documented.

3.32. The definition and selection of strategies applicable in the mitigatory domain should consider the potential usefulness of maintaining strategies initiated in the preventive domain. For example, sub-criticality of the core or the core debris should be maintained, and a path should be provided to transfer decay heat from the core or molten core debris to an ultimate heat sink, where possible.

3.33. The need to avoid or minimize the accumulation of large amounts of potentially contaminated water, including leakage caused by containment failure, should be considered in the long term strategies for storing and remediating contaminated water.

3.34. Strategies should be documented and maintained, including strategies for using non-permanent equipment; the technical background should be included in this documentation. Changes to the documentation should contain a record of previous strategies and the basis for changes.

Accident management guidelines

3.35. The strategies and measures selected in the previous section should be converted to procedures for the preventive domain (EOPs) and guidelines for the mitigatory domain (SAMGs). 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. SAMGs should contain the necessary information and instructions for the responsible personnel to successfully implement the strategies, including the use of equipment.

3.36. Accident management guidance including procedures and guidelines should be

containment pressurization; containment at sub-atmospheric pressure; release of fission products to the environment; and damage to the spent fuel pool.

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. Instructions contained in SAMGs should be written in a clear and unambiguous way so that they can be readily executed under high stress and time constraint conditions. SAMGs should contain sufficient detail to ensure the focus is on the necessary actions. For example, where primary injection is recommended, it should be identified whether this should be initiated from dedicated sources (borated water) or alternate sources (possibly non-borated water, such as fire extinguishing water). In addition, the available line-ups to achieve the injection should be identified and guidance should be put in place to enable the configuring of unconventional line-ups, where these are needed. It should be indicated how long water sources will be available, and what needs to be done either to replace such water sources or to restore them once they are depleted.

3.37. SAMGs should be written in such a way that there is provision for sufficient latitude to deviate from an anticipated path where this might be necessary or beneficial. Such flexibility may be necessary owing to the uncertainty in the status of the plant and in the effectiveness and/or outcome of actions, and in order to cover unexpected events and complications.

3.38. The severe accident management programme should be established to ensure that accident management guidance including procedures and guidelines is not adversely impacted by plant changes, including plant modifications and changes to operating procedures and training programmes.

3.39. Human and organizational factors aspects should include consideration of;

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

3.40. The team developing accident management guidance including procedures and guidelines, such as the plant vendor or designer, should consider the potential loss of the command and control structure due to damaged infrastructure, for example from an extreme external hazard, and should develop associated guidance that takes account of the following:

- The number of affected units (the reactor core and spent fuel pools);
- The functionality and habitability of control facilities;

- Damage to essential structures and buildings;
- The availability of AC and DC power required for operation of plant systems;
- Access to essential buildings and equipment;
- The availability of operating personnel and site staff for implementation of procedures and guidelines;
- Whether actions can be taken by non-licensed personnel, typically an auxiliary operator;
- The availability of other on-site control rooms and personnel in separate buildings;
- The capability of communicating within the plant emergency command and control structure and with off-site organizations.

3.41. Where immediate attention and short term actions are necessary to manage an accident, there may be no time available for the deliberation of all possible consequences of the actions. For such cases, the SAMGs should directly identify the recommended action.

3.42. The accident management guidance including procedures and guidelines should contain, as a minimum ,the following elements:

- The objectives and goals of the SAMGs;
- The interface with the EOPs;
- The criteria for entry into the mitigatory domain;
- Potential negative consequences of the actions;
- Guidance on the monitoring of strategies;
- Cautions and limitations;
- The equipment and resources necessary (e.g. AC and DC power, water);
- Consideration of necessary human resources;
- Consideration of the habitability of workplaces at which local measures for accident management may be necessary;
- Guidance on the use of diagnostic tools and computational aids;
- The time window within which the actions are to be applied;
- Local actions sheets (if applicable);
- Conditions for exit from or termination of SAMGs;
- Guidance on the assessment and monitoring of the plant response including consideration of the effectiveness of implemented actions.

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

3.44. Specific attention should be paid to situations where instrumentation is lost or incorrect due to a loss of power or a harsh environment. Procedures and guidelines should be provided for making adequately informed decisions in such cases.

3.45. In the preventive domain, it may be possible to diagnose the accident on the basis of an appropriate procedure and plant alarms. SAMGs should be put in place for situations where such a diagnosis cannot be obtained or, when it has been obtained, it later has been found to be incorrect or has changed owing to the evolution of the accident. Alternatively, the SAMGs can be fully linked to the observed physical state of the plant, so that further diagnosis of the accident sequence is not necessary. The SAMGs should be aimed at monitoring, preserving or restoring the fundamental safety functions by means of the selected strategies.

3.46. Although in the mitigatory domain it should not be necessary to identify the accident sequence or to follow a pre-analysed accident sequence in order to use the SAMGs correctly, the main control room staff and the technical support centre staff should be able to identify the challenges to fission product barriers and the plant damage state based on the monitoring of plant parameters.

3.47. The SAMGs should be developed in such a way that the potential for an erroneous diagnosis of the plant condition is minimized. The use of redundant and diverse instrumentation and signals is recommended. If there is no redundancy, preference should be given to the use of instrumentation that is designed to withstand the environmental conditions of the accident.

3.48. The SAMGs should be written in such a way that there is a possibility of deviating from the recommended strategies where this might be necessary or beneficial.

3.49. Priorities should also be defined among the various SAMGs in accordance with the priority of the underlying strategies. Conflicts in priorities, if any, should be resolved. Priorities may change in the course of the accident and, hence, the SAMGs should contain a recommendation that the selection of priorities be reviewed on an ongoing basis. The selection of actions should then be changed accordingly.

3.50. The set of accident management guidance including procedures and guidelines that is to be implemented during severe accidents should be integrated with each other to establish a comprehensive strategy for severe accident management.

3.51. A transition point from the preventive domain to the mitigatory domain should be set with careful consideration of the timing and magnitude of subsequent challenges to fission product barriers. Specific and measurable parameter values should be defined for the transition to the use of SAMGs such as, for example, the measured value of the core exit temperature. When the transition point is specified on the basis of conditional criteria (i.e. if certain planned actions in the EOPs are unsuccessful), the time necessary to confirm that the transition point has been reached should be taken into account. For example, as the fuel temperature rises, the degree of fuel degradation will affect the anticipated time needed for identification of the transition point.

3.52. Protocols for communicating with various interested parties when the transition point has been met or exceeded should be carefully considered. Steps should be taken to ensure that all personnel understand how their roles are about to change during the transition.

3.53. The possibility of transition from EOPs to SAMGs before the technical support centre is operable should be considered in the development of procedures and guidelines. This situation can occur in cases where an event rapidly develops into a severe accident, or where the technical support centre cannot be activated within the time assumed in the guidance. Any mitigatory guidance provided to main control room staff in this case should be presented in a way that makes prompt and easy execution possible and, therefore, should be presented in a format that operators are able to work with and are already trained for.

3.54. Proper transition from EOPs to SAMGs should be provided for, where appropriate. Functions and actions from the EOPs that have been identified as relevant in the mitigatory domain should be retained in the SAMGs.

3.55. Where EOPs are not exited but are executed in parallel with the SAMGs, their applicability and validity in the mitigatory domain should be demonstrated. In such cases, a hierarchy between EOP and SAMG actions should be established, in order to address possible conflicts.

3.56. In addition to entry conditions to the SAMGs, exit conditions or criteria to long term provisions should be specified. A long term safe stable state should be clearly defined and provisions to maintain the long term safe stable state should be specified.

3.57. Accident management guidance including procedures and guidelines should be based on directly measurable plant parameters. Where measurements are not available, parameters should be estimated by means of simple computations (e.g. using steam tables) and/or pre-calculated graphs.

3.58. It should be noted that various pieces of equipment may start automatically or change configuration when certain parameters reach pre-defined values (‘set points’). Such automatic actions may have been designed for events in the preventive domain but may be counterproductive in the mitigatory domain. Hence, all automatic actions should be reviewed for their impact in the mitigatory domain and, where appropriate, automatic actions that are not appropriate for the mitigatory domain should be inhibited. The need for manual actions in respect of the equipment concerned should then be considered in the guidance.

3.59. Accident management guidance including procedures and guidelines should contain the preferred accident management equipment that is available. Alternate methods for achieving the same purpose should be explored to account for the possible failure of this equipment and, if available, should be included in the guidance. For example, possible equipment failures include instrumentation failure or equipment lockout, and the availability of alternative equipment should be determined

3.60. Accident management guidance including procedures and guidelines should include recommendations on the priorities for restoration actions. In this context, the following should be considered:

- Possibilities to restore the equipment;
- Possibilities for unconventional system line-ups;
- Possibilities to connect portable equipment;
- Successful recovery times when several pieces of equipment are out of service;
- Dependence on a number of failed support systems;
- Doses to personnel involved in the restoration of the equipment or the connection of portable equipment.

3.61. The time to recover unavailable equipment or to connect non-permanent equipment may be outside the time window to prevent core damage. If this is the case, an earlier transition to the mitigatory domain can be decided on.

3.62. In the development of accident management guidance, account should be taken of the habitability, operability and accessibility of the main control room and the technical support centre. The accessibility of other relevant areas, such as areas for local actions, should also be assessed and taken into account in the development of accident management guidance. It should be investigated whether expected dose rates and other environmental conditions may give rise to a need for restrictions on personnel access to such areas and, if this is found to be the case, appropriate measures should be considered.

3.63. When containment venting leading to releases of radioactive material is considered or directed in severe accident management, the following should be considered in the accident management guidance:

(a) Situations when all AC and DC power is lost and compressed air is not available;
(b) Situations involving high radiation areas and high temperatures in areas where vent valves are located (if local access is required);
(c) The notification of relevant off-site response organizations of actions involving off-site consequences.
(d) Limitation of radioactive releases in case of containment venting should be ensured as far as possible through such means as aerosol deposition, filtration, or early venting.

3.64. Pre-calculated graphs or simple formulae should be developed, where appropriate, to avoid or limit the need for complex calculations during the accident. These are often called 'computational aids' and should be included in the documentation of the SAMGs. Computer based aids should consider the limited battery life of self-contained computers (laptops) and the potential for loss of AC power.

3.65. Rules of usage should be developed for the application of the accident management guidance. Questions to be addressed should include at least the following:

- If while executing EOPs an entry point for an SAMG is reached, should actions in the EOP then be stopped or continued, if not in conflict with the applicable SAMG?
- If an SAMG is in execution, but the point of entry for another SAMG is also reached, should that other SAMG be executed in parallel?
- Should the consideration to initiate another SAMG be delayed while parameters that called upon the first SAMG are changing value?

3.66. Adequate background documentation material should be prepared to support the development of SAMGs and it should be included as references for main control room staff and technical support centre staff. The background material should fulfil the following objectives:

(a) It should be a self-contained source of reference for:
- The technical basis for strategies and deviations from generic strategies, if any;
- A detailed description of instrumentation needs;
- Results of supporting analysis;
- A detailed description of and the basis for steps in procedures and guidelines;
- The basis for specification of set-points used in the SAMGs;

(b) It should provide basic material for training courses for staff involved in accident management.

3.67. Relevant management levels in the operating organization of the plant as well as outside organizations, including local authorities responsible for protection of the public and protection of the environment, should be made aware of the potential need for transition to the mitigatory domain.

3.68. Potential changes to the EOPs or SAMGs should first be made to the relevant background documentation to ensure the changes are thoroughly evaluated. Such updated background documentation and EOPs and SAMGs should be issued to the operating organization simultaneously for validation and training.

3.69. The team involved in the development of accident management guidance should contain staff responsible for the development and implementation of the severe accident management programme in the plant. The development team should ensure the involvement of staff from the training department, operations staff, maintenance staff, radiation protection staff, staff responsible for instrumentation and control systems, engineering staff, persons responsible for emergency preparedness and response and external experts, as appropriate. If use of a generic severe accident management programme has been selected, experts familiar with this severe accident management programme may support the development team.

3.70. The main control room staff, supplementary control room staff, technical support centre staff and staff of any other organizational unit responsible for evaluation, decision making and implementation of accident management actions in the course of an accident should be involved at an early stage of development of a severe accident management programme.

3.71. Consideration should be given to the way in which plant personnel will be made available to participate in the development activities of the severe accident management programme in addition to their normal duties. Sufficient time should be granted to plant personnel on the development team in relation to their other obligations.

Accident management for multiple unit sites

3.72. In the case of multiple unit sites with shared safety related equipment or systems, the possible continued use of a unit that has not been affected should be taken into account in the accident management guidance. Pre-defined criteria should be established to decide whether or not the operating units at the same site should be shut down in the event of a severe accident.

3.73. Requirement 33 of SSR-2/1 (Rev. 1) [2] states that "Each unit shall have its own safety systems and its own safety features for design extension conditions." However, the sharing of support systems does occur in old plants. Special care should be used for existing plants to identify the potential impact on any equipment or systems that might be shared between units, in particular from the point of view of adequate capacity of the shared systems. In particular, safety systems should not be shared between multiple units unless this contributes to enhanced safety for design extension conditions, including severe accidents.

3.74. Current design requirments state that each unit of a multiple unit nuclear power plant is required to meet Requirement 33 of SSR-2/1 (Rev. 1) [2]). To further enhance safety, means of allowing interconnections between units of a multiple unit nuclear power plant are required to be considered in the design for accident management (see para. 5.63 of SSR-2/1 (Rev. 1) [2]).

3.75. The effectiveness of equipment and the emergency response facilities (e.g. the main control room and/or the technical support centre) that are shared by different units should be assessed for cases where accidents, including accidents more severe than the design basis accidents, occur simultaneously at several units.

3.76. If structures, systems, and components that are used for severe accident management are shared between different units, an assessment should be performed as to whether safe shutdown will be achievable for the other units in the event of an accident at one unit.

3.77. When other units are located at a neighbouring site close to the site at which an accident has occurred, sharing of information with the operating organizations of those neighbouring units should be considered, so as to determine whether expected dose rates and other environmental conditions due to dispersion of radioactive material from the units at the neighbouring site may affect access to the site at which the accident has occurred.

3.78. The SAMGs should address the possibility that more than one unit, or all units, may be affected concurrently by simultaneous accidents, including the possibility that damage propagates from one unit to another, or that damage to one unit is caused by actions taken at another unit.

HARDWARE PROVISIONS FOR ACCIDENT MANAGEMENT

3.79. For existing plants, changes in the design should be evaluated where the radiological consequence of challenges to fission product barriers cannot be reduced to an acceptable limit, or to reduce uncertainties in the analytical prediction of such challenges. Such evaluation should include considerations of regulatory acceptance criteria.

3.80. For new plants, when additional equipment is provided to mitigate the consequences of severe accidents, such equipment should preferably be independent from equipment and systems used to cope with design basis accidents.

3.81. Equipment upgrades (of permanent or non-permanent equipment) aimed at enhancing preventive features of the plant should be considered as tasks with high priority. For existing plants, the provision of non-permanent on-site or off-site equipment (reasonably protected against external hazards) may be an option to enhance the preventive capabilities of the plant.

3.82. Equipment upgrades aimed at maintaining the integrity of the containment or aimed at minimizing releases when the containment has failed or been by-passed, should be considered as a high priority.

3.83. Upgrades should be considered that increase the capability of the equipment, or its margin to failure, against relevant challenges for the following functions:

- Instrumentation for the monitoring of essential containment parameters, such as temperature, pressure, radiation level, hydrogen concentration and water level;
- Ensuring the leak-tightness of the containment, including preservation of the functionality of isolation devices, penetrations and airlocks, for a reasonable time

after an accident;

- Establishing or restoring the ultimate heat sink to manage pressure and temperature in the containment;
- Control of combustible gases, fission products and other materials released during a severe accident;
- Monitoring and control of containment leakages and of fission product releases;
- Removing the produced heat from the molten core debris to an ultimate heat sink.

3.84. Additional hardware provisions should be considered, including the provision of non-permanent on-site and off-site equipment as a back-up measure, where the existing equipment is not anticipated to remain functional in the long term or could be disabled in case of total loss of AC power or extensive infrastructure damage caused by extreme external hazards. In estimating the long term availability of components, the feasibility of performing maintenance or repairs should be evaluated and taken into account.

3.85. Non-permanent equipment necessary for accident management should be stored and protected so that it will be ready for use within a predefined timeframe.

3.86. When the accident management strategies rely on non-permanent equipment, the survivability of such equipment for anticipated conditions and for the actual configuration and layout should be assessed to determine whether it is likely to meet accident management objectives. Steps should be taken to ensure that personnel can install and operate the non-permanent equipment within the timeframes necessary, taking into account possible adverse conditions.

3.87. Heavy machinery which removes rubble due to extreme external hazards should be provided with consideration of bad weather conditions for its use or interconnect among multiple units.

3.88. The non-permanent equipment should be located in diverse positions to the extent practicable, so as to avoid common cause failures due to external hazards such as earthquake and tsunami.

3.89. Consideration should be given to the provision of multiple hook-up points to facilitate the use of non-permanent equipment during an accident caused by external hazards, taking into account both the benefits and the potential negative implications.

3.90. Maintenance, testing and inspection procedures should be developed for equipment including non-permanent equipment to be used in accident management according to its safety significance and manufacturer's recommendations..

Hardware provisions for severe accident management at multiple-unit sites

3.91. In installing equipment (both permanent and non-permanent equipment) for use in accident management, consideration should be given to the possibility of severe accidents occurring simultaneously at more than one unit.

3.92. For existing plants, the use of a containment venting system that is shared between more than one unit should not have a detrimental impact on the other units on the site.

3.93. Site personnel should consider using any available and inter-connectable equipment among units during severe accidents at the multi-unit sites.

INSTRUMENTATION AND CONTROL FOR ACCIDENT MANAGEMENT

3.94. Essential instrumentation necessary for monitoring the conditions of the core, the containment and the spent fuel should be identified. To the extent practicable, these monitoring functions should be maintained throughout an extended loss of AC power. A plant specific assessment should be performed to identify the necessary equipment, materials and actions to restore power to the minimum essential components in the event that installed DC batteries are depleted.

3.95. An accident management strategy for obtaining information for alternate sources of information should be prepared for the event that the plant parameters derived from instrumentation are not reliable.

3.96. An accident management strategy for disconnecting non-essential loads from batteries should be prepared in advance, to extend battery life until such time as the battery can be recharged or an alternate power source can be provided.

3.97. Accident management guidance should be provided on validating important instrumentation outputs (i.e. outputs used for symptom based diagnosis of potential challenges to fission product barriers or for confirmation of the effectiveness of implemented strategies). All important instrumentation readings should be verified with other independent information where possible. The need for such verification should be emphasized in exercises and drills.

3.98. All available information and background documentation on essential instrumentation necessary for supporting decision making in accident management should be made available to appropriate members of the emergency response teams.

3.99. The uncertainty of readings of instruments essential for accident management should be assessed. In many cases, instrument indication that permits trending may be more important than the accuracy of the indicated values.

3.100. The survivability of instrumentation essential for accident management should be carefully considered. Instrumentation might continue to operate beyond its design range with decreasing accuracy. The following should be taken into account:

- The use of instrumentation that is designed for the expected environmental conditions following an accident should be the preferred method of obtaining the necessary information.
- Alternate instrumentation should be identified if the preferred instrumentation becomes unavailable or is not reliable.

Additional means (such as computational aids) or contingency plans including engineering judgment should be developed for the case where such instrumentation is not available.

3.101. The effect of environmental conditions on the instrument reading should be estimated, taking into account that the local environmental condition can deviate from global environmental conditions and so instrumentation that is qualified under global conditions may not function properly under local conditions. The expected failure mode and resultant instrument indication (e.g. off-scale high, off-scale low, floating) for instrumentation failures in severe accidents should be identified.

ANALYSES FOR DEVELOPMENT OF A SEVERE ACCIDENT MANAGEMENT PROGRAMME

3.102. The development and implementation of the severe accident management programme should be supported by appropriate computational analysis showing the progression of representative accident sequences to be addressed by accident management, with the results of such analysis to be used for formulation of the technical basis for development of strategies, procedures and guidelines. The results of accident analysis should assist in the following:

- Specification of the criteria that would indicate the onset of severe core damage;
- Identification of the symptoms (i.e. parameters and their values) by which staff may determine the condition of the reactor core and the state of protective barriers;

- Identification of the challenges to fission product barriers in different reactor states, including shutdown states;
- Evaluation of the timing of such challenges to improve the potential for successful human intervention;
- Identification of the reactor systems and material resources that may be used for accident management purposes;
- Verification that accident management measures would be effective to counter challenges to protective barriers;
- Evaluation of the performance of equipment and instrumentation under accident conditions;
- Development and validation of computational aids for accident management.

3.103. Plant capabilities should be analysed in connection with the in-vessel phase of a severe accident as follows:

- Hydrogen production in the vessel and its release, as input information for the design of the hydrogen treatment system;
- Retention of the molten core within the vessel both by internal and external vessel cooling;
- The composition and configuration of the molten core, and failure of the reactor pressure vessel, as input for the design of the core catcher;
- Reliable depressurization to allow low-pressure water injection and avoid high pressure vessel failure;
- Long term release of fission products from the reactor core;

3.104. For the ex-vessel phase, plant capabilities should be analysed including:

- Reliable depressurization of the containment to avoid high pressure containment failure;
- Sources and the distribution and the potential leak paths as input information for the design of the combustible gas treatment system;
- Issues relating to ex-vessel steam explosion, high pressure melt ejection and direct containment heating;
- Composition and configuration of the molten core, as input for the design of ex-vessel melt retention devices;

- Fission product sources and the distribution of fission products within the containment, with special attention given to the long term behaviour of such sources.

3.105. Best estimate computer codes assumptions and data regarding initial and boundary plant conditions should be used providing appropriate consideration is given to uncertainties in the determination of the timing and severity of the phenomena.

3.106. All significant sources of radioactive material in the plant, including the reactor core and spent fuel pools, and the occurrence of accidents in all relevant normal operating and shutdown states (including open reactor or open containment barriers) should be addressed.

3.107. All phenomena (e.g. thermohydraulic and structural phenomena) important for the assessment of challenges to the integrity of barriers against releases of radioactive material, as well as for assessment of the source term should be addressed. Accidents affecting multiple units should be analysed for sites that have more than one unit.

3.108. A sufficiently broad set of accident sequences adequately covering the potential evolution of accidents and a comprehensive set of plant damage states should be identified. Such accident sequences should be grouped into representative plant damage states[11]. Level 1 PSA and Level 2 PSA, if available, in combination with engineering judgement should be used for the selection of the accident sequences (see SSG-3 [15] and SSG-4 [16]).

3.109. If generic plant analysis is used for the development of accident management guidance, an assessment of its applicability for the specific plant should be performed.

3.110. Plant specific data, including plant operational parameters, the configuration of plant systems and performance characteristics and set-points, should preferably be used for the analyses.

3.111. Sufficient input for the development of accident management guidance including procedures and guidelines should be provided regarding in particular:

- The choice of symptoms for diagnosis and monitoring the course of the accidents;
- The identification of the key challenges and vulnerable plant systems and barriers;
- The specification of set-points to initiate and to exit individual strategies;
- The positive and negative impacts of accident management actions;

[11] Many categorization schemes are possible. SSG-4 [16] contains such categorization schemes for Level 2 PSA.

- The time windows available for performing the actions;
- The prioritization and optimization of strategies;
- The evaluation of the capability of systems to perform their intended functions;
- The expected trends in the accident progression;
- The exit conditions for leaving the severe accident management domain;
- The development of computational aids.

3.112. Sufficient information regarding environmental conditions should be provided for the assessment of the survivability of the plant equipment, including the instrumentation necessary in accident management, as well as for the assessment of the working conditions and the habitability of working places for personnel involved in the execution of the accident management actions.

3.113. Accident sequences involving inappropriate operator actions (errors of omission or errors of commission) leading to core damage should be considered.

3.114. Computer codes should be used that have the capability of modelling severe accident phenomena with reasonable accuracy in the prediction of key physical phenomena, and modes and timing of failure of barriers, and should be validated to the extent practicable.

3.115. All analysis results should be evaluated and interpreted with due consideration given to code limitations and associated uncertainties. The appropriateness of carrying out sensitivity analyses should be evaluated when computer code results are relied upon for making critical decisions. (Further information on code limitations and associated uncertainties for severe accident analysis is provided in Ref. [19]

STAFFING, QUALIFICATION AND WORKING CONDITIONS FOR ACCIDENT MANAGEMENT

Staffing and qualification

3.116. A nominative list of persons that will be part of accident management should be established and these persons should be designated as emergency workers. This list should take into account accidents developing over a long period so that adequate shift staffing is maintained at the plant (e.g. during holidays and nights).

3.117. Adequate staffing levels and personnel qualifications should be established for the implementation of accident management measures, taking into account the possibility that all units can be affected concurrently by simultaneous accidents and taking into account the requirements for emergency response (see GSR Part 7 [6]). Staffing levels should be such that an adequate response can be sustained until additional support in staff arrives.

Working conditions

3.118. Acceptable habitability should be provided for plant staff and external support staff in situations where the site is partially or totally isolated from continuous off-site support.

3.119. Shift turnover documents should be maintained to allow continuity during shift changes. During turnovers, staff on the new shifts should be provided with accident related information as well as other information deemed necessary to maintain continuity in strategies for managing the accident.

3.120. Contingency plans should be developed for the following:

- Situations where staff involved in accident management have been incapacitated;
- Situations when some staff involved in accident management need to be evacuated;
- Situations when outside support may be delayed so that main control room staff and technical support centre staff will need to continue the accident management measures.

3.121. As part of overall emergency preparedness, arrangements should be put in place to help staff cope with emotional stress affecting performance during the response, in relation to both the circumstances of the accident and any conventional emergency that is occurring simultaneously and affecting their families and/or property.

3.122. Suitable, reliable and diverse means of communication should be available at all time for use on the site and for communication with off-site authorities, and guidance should be put in place for measures to be taken if some or all of these means fail. The effects of a station blackout and the potential for damage of the communication equipment from extreme external hazards should be considered in these arrangements.

RESPONSIBILITIES, LINES OF AUTHORIZATION AND INTERFACES WITH EMERGENCY PREPAREDNESS AND RESPONSE FOR ACCIDENT MANAGEMENT

Responsibilities and lines of authorization

3.123. The authority and responsibility for deciding on actions to be taken on the site during an accident should be assigned and the relevant individual should be provided with training to promptly discharge this authority. This person should be trained to lead under extreme conditions and should demonstrate his or her leadership abilities during exercises.

3.124. Responsibilities and authorities for the implementation of certain accident management measures on the site with a potentially significant impact on the site and/or off the site should be assigned within the on-site emergency response organization. An example layout of the organizational structure of the on-site emergency response organization is depicted in Fig. 2. (For examples of on-site emergency response organizations, incorporating various elements beyond those considered here, refer to the figures in appendix 13 in Ref. [20])

3.125. The on-site emergency director (or other person with clearly assigned authority for making decisions on the on-site actions to be taken) should have the authority to take any necessary actions to mitigate the consequences of the accident without the need for external authorization, including venting the containment or injecting low quality water into the reactor pressure vessel or steam generator (see paras 4.15 and 5.23 of GSR Part 7 [6]). However, in case such actions have off-site consequences, the appropriate off-site authorities should be notified.

3.126. Personnel involved in accident management should be designated as emergency workers, and may have one of three categories of function:

(1) Evaluation or recommendation (assessment of plant conditions, identification of potential actions, evaluation of the potential impacts of these actions, and recommendation of actions to be taken and, after implementation, assessing the outcome of actions): personnel in charge of such duties are often called ‘evaluators’;

(2) Authorization (decision making – approving the recommended action or deciding other appropriate actions for implementation): personnel in charge of such duties are often called ‘decision makers’;

(3) Implementation and support of the actions (operation of equipment as necessary, including verification of operation, dose assessment in support of accident management actions, emergency response functions): personnel in charge of such duties are often called ‘implementers’ or ‘responders’. This includes remote operations from the main control room, and also local actions by appropriate personnel to recover or connect equipment.

3.127. Emergency arrangements should take into account cases in which an individual with a certain authority level is incapacitated and should identify an alternative person to discharge the authority.

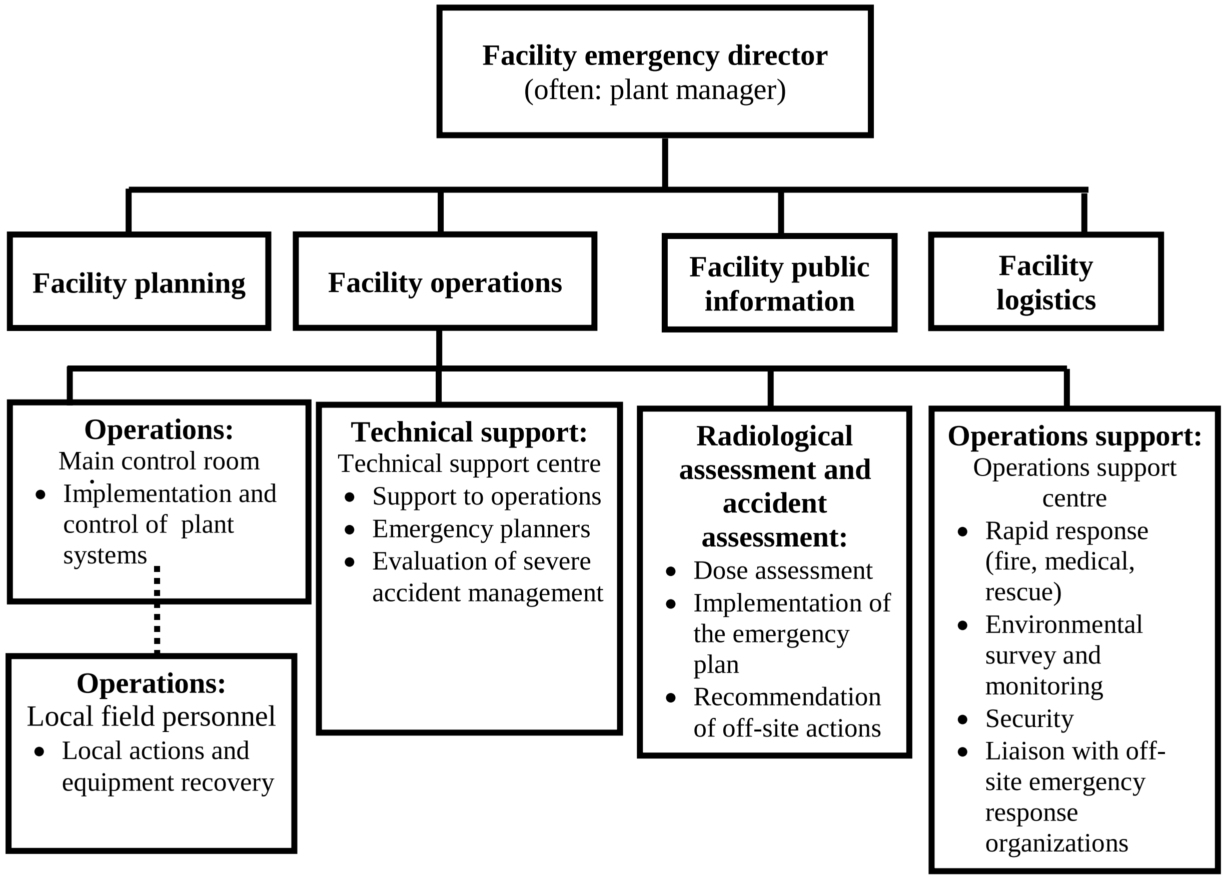

FIG..2 Example layout of the organizational structure of the on-site emergency response organization.

3.128. When off-site support for accident management needs to be obtained, consideration should be given to ensuring coordination and to minimizing the possibility of negative interaction between actions performed by various teams on the site. Accident management should be implemented such that that all teams have a common situational awareness.

3.129. The decision making authority should lie with a high level manager, denoted in this Safety Guide as the emergency director. The emergency director should be granted the authority to decide on the implementation of accident management measures, taking into account those proposed by the staff of the technical support centre. The emergency director should maintain a broad understanding of the actual status of the plant, the plant capabilities and vulnerabilities and key accident management actions, including their on-site and off-site consequences.

Transfer of responsibility and authority

3.130. The points at which authority for decision making and implementation of accident management actions is transferred should be clearly established.

3.131. Transfer of responsibilities and decision making authority from the main control room staff to an appropriate level of authority of the technical support centre should be made if an event is likely to degrade into a severe accident and decision making becomes highly complex in view of the uncertainties involved.

3.132. In transferring the overall authority for accident management from the main control room to the technical support centre[12], the functions that remain in the main control room and the actions that can be decided upon by the main control room staff independently of the emergency director should be specified. These include activities that main control room staff can carry out independently, such as maintaining support conditions (e.g. service water for room cooling) and responding to some alarms; activities that the main control room staff should not do on their own (e.g. starting up major equipment) should also be specified. As the staff of the main control room staff are also responsible for the execution of the measures decided upon by the emergency director, consistency and a hierarchy between the two groups of actions should be established.

3.133. If transfer of authority within the operating organization is considered during an accident, it should be verified that the person to whom authority will be transferred has the required background to efficiently discharge such authority.

3.134. The transfer of authorities and responsibilities during the emergency response should take place at a point in time that minimizes any risks to safe and effective implementation of accident management measures and, thus, is optimal from the viewpoint of accident management. The transfer of responsibility and authority should not create a ‘vacuum’ in decision making and in implementation of necessary actions. Hence, any formal transfer of responsibility and authority should not take place until the new decision maker is ready to assume his or her role. Arrangements for the transfer of responsibilities and authorities should be consistent with the arrangements addressed in the on-site emergency plan.

[12] In some States, the transfer of responsibility for emergency response to the authorized person occurs when this person arrives at the emergency response organization in all cases, irrespective of severity of the accident. Also in some States the authorized person (or their replacement) will retain decision making authority until a long term safe and stable state is achieved.

Technical support centre

3.135. Criteria for activation of the technical support centre should be unambiguous and clearly specified in plant procedures and the on-site emergency plan. Accident management measures should continue to be decided on and carried out by the control room staff until the technical support centre is functional, with sufficient staff present and having acquired awareness of the situation. GS-G-2.1 [8] recommends that the technical support centre be activated and functional within one hour following the declaration of an emergency. Additional details are provided in para. 4.2 of this Safety Guide.

3.136. Depending on the situation, the technical support centre may be activated in the preventive domain. In such cases, the technical support centre should provide technical support to the staff of the main control room.

3.137. Selected staff of the technical support centre should have a detailed knowledge of the procedures and guidelines for severe accident management. They should have prompt access to the information on the plant status and a good understanding of the underlying accident phenomena. The staff of the technical support centre should communicate as necessary with the staff of the main control room to benefit from their expertise of and insight into the plant capabilities.

3.138. Support from qualified organizations including the plant vendor or designer should be sought, as necessary, for additional recommendations on appropriate accident management measures. The mechanisms for calling on early support should be established so that it allows for effective implementation of the severe accident management programme, and the capabilities of such support organizations should be verified and tested on a periodic basis.

3.139. Rules for information exchange between the various teams of the on-site emergency response organization and with off-site response organizations should be defined. The mechanisms for ensuring the flow of information between the technical support centre and the main control room, as well as from the technical support centre to other parts of the on-site emergency response organization, including those responsible for the execution of on-site and off-site emergency plans, should be specified. Oral communication between the technical support centre and the main control room staff should be done by a member of the technical support centre staff who is a licensed operator or a similarly qualified person. As the occurrence of a severe accident will generate extensive communication between on-site and off-site teams, care should be taken that this communication does not disrupt the management of the accident at the plant.

3.140. Information about the performance of the instrumentation and control and other equipment (possibly already summarized in the guidance for easy reference) should be made available to the technical support centre. Preferably the technical support centre should have direct access to plant information. Where the manual transfer of plant data between main control room and the technical support centre is necessary, this should preferably be done by a dedicated member of either staff of the main control room or a dedicated member of staff of the technical support centre. The plant information in the technical support centre should be recorded and monitored appropriately.

3.141. A highly reliable communication network based on the principles of redundancy, diversity and physical separation of communication channels should be provided for communication between the main control room, the technical support centre, and off-site facilities.

3.142. Reasonable assurance should be provided that the on-site technical support centre (or emergency response facility) will be operable and habitable under a range of postulated hazardous conditions, including extreme external hazard conditions not considered in the design.

Interfaces with emergency preparedness and response

3.143. Appropriate interfaces including consideration of reliable communication between the severe accident management programme and the emergency response plans and procedures should be established for an effective and coordinated response to the nuclear or radiological emergency, both on the site and off the site.

3.144. The on-site emergency plan should define the overall functions to be performed in an emergency response, and the necessary infrastructure, such as the emergency response organization of a nuclear power plant, should be put in place to support performance of these functions, as required in GSR Part 7 [6]. The responsibilities defined in the severe accident management programme should be coordinated with the emergency plan in order to ensure a consistent and integrated response to severe accidents. A review of the emergency plan and the severe accident management programme (including the EOPs and SAMGs) and their testing in exercises should be performed on a regular basis in order to ensure that conflicts do not exist or they are noted and avoided at the preparedness stage.

Responsibilities, lines of authority and interfaces for multiple unit sites

3.145. For multiple unit sites, the on-site emergency plan should include the necessary interfaces between the various parts responsible for different units of the overall on-site emergency response organization. Emergency directors for each unit may be assigned to decide on the appropriate actions at specific units. In this case, an overall emergency director should also be assigned to coordinate activities and priorities amongst all affected units on the site. Decision making responsibilities should be clearly defined. In case of different operating organizations at a given site, appropriate arrangements should be established on coordination of emergency response operations, including accident management measures, among the operating organizations.

VERIFICATION AND VALIDATION OF THE SEVERE ACCIDENT MANAGEMENT PROGRAMME

3.146. Verification and validation processes should assess the technical accuracy and adequacy of the instructions to be extent possible, and the ability of personnel to follow and implement them. The verification process should confirm the compatibility of instructions with referenced equipment, user aids and supplies (e.g. non-permanent equipment, posted job aids and computational aids) (see Ref. [18]). The validation process should demonstrate that the necessary instructions are provided to implement the guidance.

3.147. Validation tests should address the organizational aspects of accident management, especially the roles of the evaluators and decision makers, including the staff in the main control room and in the technical support centre.

3.148. Accident management guidance including procedures and guidelines should be verified and validated. Changes made to procedures and guidelines should be re-evaluated and re-validated, on a periodic basis, to maintain the adequacy of the severe accident management programme.

3.149. Possible methods for validation of the procedures and guidelines are an engineering simulator including a full scope simulator (if available) or other plant analysis tool, or a tabletop method. The most appropriate method or combination of methods should be selected, taking into account the role of each functional group of personnel (see para. 3.122) in an emergency.

3.150. If a full scope simulator is used, validation should encompass the uncertainties in the magnitude and timing of phenomena (both phenomena that result from the accident progression and phenomena that result from recovery actions). Consideration should be given to simulating a degraded or unavailable instrumentation response, or a delay in obtaining the information.

3.151. Validation should be performed under conditions that realistically simulate the conditions present during an emergency and include simulation of other response actions, hazardous work conditions, time constraints and stress. Special attention should be paid to the use of portable and mobile equipment, when such use is considered, and, for multiple unit sites, to the practicality of using backup equipment that could be provided by other units.

3.152. A cross-functional safety review of the plant should be performed with the objective of fully understanding all implications of accident management. This review should incorporate a plant walk-down for assessing the difficulties associated with practical implementation of accident management measures in case of internal or external hazards.

3.153. All equipment necessary for the severe accident management programme, including non-permanent equipment, should be tested in accordance with the importance of the equipment to fulfilling the fundamental safety functions.

3.154. Accident management guidance should be prepared for testing the permanent and non-permanent equipment and for testing any assembled sub-systems necessary for the equipment to meet its planned performance. The frequency and type of testing should be conducted in accordance with the manufacturer's recommendations. Tests should address the necessary local actions, contingencies and the proper connection of the non-permanent equipment to plant equipment, access to the site, off-site actions, the possibility of events affecting multiple units, emergency lighting, and the time needed to implement these actions, if appropriate. Accident management guidance should be provided for maintenance and periodic testing to ensure the proper functioning of equipment.

3.155. Staff involved in the validation of the procedures and guidelines should be different from those who developed the accident management guidance including procedures and guidelines. Developers and writers of plant specific accident management guidance including procedures and guidelines should prepare appropriate tests and scenarios for validation and their participation as observers to the validation process may be beneficial (see Ref. [21]).

3.156. The findings and insights from the verification and validation processes including consideration of positive and negative consequences of actions should be documented. This information should be used for providing feedback to the developers of procedures and guidelines for any necessary updates before the documents are brought into force by the management of the operating organization. The documentation should be stored appropriately to enable any future revalidation.

TRAINING, EXERCISES AND DRILLS FOR ACCIDENT MANAGEMENT

3.157. Personnel responsible for performing accident management measures should be trained to acquire the required knowledge, skills and proficiency to execute their tasks. A comprehensive training programme for accident management should be prepared that includes the interfaces with emergency preparedness and response. Training should include a combination of techniques, such as classroom training, drills, tabletop exercises[13] and the use of simulation tools.

3.158. Decision makers should be trained to understand the consequences and uncertainties inherent in their decisions, evaluators should ensure that they understand the technical basis upon which they will base their recommendations and implementers should ensure that they understand the actions that they may be asked to take. The decision makers also should be trained so that they can cope with the situation in which some mitigatory actions might be necessary based on the loss or unreliability of plant instrumentation.

3.159. Training should be developed using a systematic approach to training [22]. This includes identifying training needs, defining the training objectives, specifying the technical basis for training material, developing training material, specifying the appropriate venue for delivering training and measuring the effectiveness of training to provide feedback to the training process.

3.160. Training should be developed and implemented for each on-site group and off-site group involved in accident management. Training should be commensurate with the tasks and responsibilities of the participants, taking into account the appropriate technical level for each group. In-depth training should be considered for personnel entrusted with critical functions in the severe accident management programme.

3.161. Training material should be developed by subject matter experts and qualified

[13] A tabletop exercise is a structured discussion exercise among decision makers or responders, based on a scenario or set of conditions representing a potential emergency response situation. The objective is both educational and developmental in that misunderstandings, incorrect perceptions and errors in procedures can be identified easily and then corrected.

trainers. Experts could assist in:

- Answering questions that are beyond the capability of professional trainers;
- The operation of field and local equipment and the operation of equipment under adverse conditions, including the use of non-permanent equipment.

3.162. Training, including periodic exercises and drills, should be sufficiently realistic and challenging to prepare personnel responsible for accident management duties to cope with and respond to situations that may occur during an event. Drills should extend over a time period long enough to realistically represent the plan response and should allow for testing the transmission of information during shift changes. Special exercises and drills should be developed to practice shift changeovers between operations staff and technical support centre staff and information transfer between different teams. Training should cover accidents occurring simultaneously on more than one unit, accidents occurring in different reactor operating states and accidents in the spent fuel pool. Training should consider unconventional line-ups of the plant equipment, the use of non-permanent equipment (such as diesel power generators and pumps) as well as repair of the equipment.

3.163. Training material should address the implementation of strategies under adverse environmental conditions, including conditions resulting from external hazards with potentially high radiation levels and under the influence of stress on the anticipated behaviour of staff.

3.164. Training for new staff as well as refresher training should be developed for all groups of staff involved in accident management. The frequency of refresher training should be established on the basis of the difficulty and importance of accident management tasks. A maximum interval for refresher training should be defined, but, depending on the outcome of exercises and drills held at the plant, a shorter interval may be selected. Changes in the guidance and/or use of the guidance should be reflected in the training programme consistent with the nature of the changes and such changes should be communicated to various interested parties.

3.165. Exercises and drills should be based on scenarios that require the application of a substantial portion of the overall severe accident management programme in concert with emergency response, and should simulate realistic conditions characteristic of those that would be encountered in an emergency. Large-scale exercises providing an opportunity to observe and evaluate all aspects of accident management should be undertaken.

3.166. Accident management exercises and drills should periodically challenge responders by making information sources (such as the safety parameter display system), equipment and facilities that potentially could be damaged in an accident unavailable. Drills that purposely include sources of inaccurate or miscommunicated information to personnel can be used as a way of exercising their questioning attitude, teamwork and evaluation and diagnostic skills. However, caution should be applied so that misinformation does not contribute to a negative effect of the training.

3.167. Criteria for evaluating the effectiveness of an exercise or a drill should be established. Such criteria should characterize the ability of the team participating in the exercise or drill to understand and follow the evolution of plant status, to reach well founded decisions for various events including unanticipated events, to initiate appropriate actions, and to meet the objectives of the exercise or drill (see Ref. [18]).

3.168. Some of the scenarios used for exercises and drills should assume an extensively damaged state of the core that eventually results in failure of the reactor pressure vessel and the containment. Consideration should be given to conducting exercises that enhance the awareness of main control room staff, technical support centre staff or engineering staff of the need for and possible consequences of defeating or resetting control and logic blocks for implementing some successful strategies.

3.169. Results from exercises and drills should be systematically evaluated to provide feedback for improvement of the training programme and, if applicable, the procedures and guidelines as well as the organizational aspects of accident management.

UPDATING THE SEVERE ACCIDENT MANAGEMENT PROGRAMME

3.170. The need to update the severe accident management programme should be assessed as new information becomes available that may indicate the potential for new accident scenarios, phenomena or challenges to physical barriers or any other significant effect on accident management that had not been fully considered previously.

3.171. The effect of changes to the plant design, the available non-permanent equipment and the operating organization should be evaluated for any impact on the severe accident management programme. A formal process should be developed for making changes when such changes are deemed necessary.

3.172. When modification of the severe accident management programme is deemed appropriate, the operating organization should be responsible for establishing an action plan aimed at prioritizing the activities necessary for implementation of the modifications. Where a generic severe accident management programme is used, development of the action plan should involve the vendor of the generic programme. The action plan should identify the timeframe and the organization in charge of practical implementation of the modifications.

3.173. When new information is received that challenges current design assumptions relating to external events, the capability of installed equipment and the accident management procedures and guidelines should be evaluated to determine if safety functions could be compromised. Based on this evaluation, measures for updating the severe accident management programme commensurate with the significance of the new information should be identified.

3.174. New insights from research on accident phenomena and operating experience at the plant and at other plants (including lessons identified from events) should be evaluated on a regular basis and a judgement should be made by the operating organization as to their potential impact on the severe accident management programme. Exchange of information with operating organizations of other plants should be used as a means of continuously improving the accident management guidance.

3.175. Any update of the severe accident management programme should include, as appropriate, a revision of background documentation, including the supporting analysis

MANAGEMENT OF THE SEVERE ACCIDENT MANAGEMENT PROGRAMME

3.176. Development of a severe accident management programme should be the responsibility of the operating organization and should be consistent with the applicable requirements established in SSR-2/1 (Rev. 1) [2] and IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [23] and the recommendations provided in IAEA Safety Standards Series No. GS-G-3.1, Application of the Management System for Facilities and Activities [24] and IAEA Safety Standards Series No. GS-G-3.5, The Management System for Nuclear Installations [25] as well as applicable international standards or national requirements.

3.177. The operating organization should integrate all the elements of the severe accident management programme within its management system so that processes and activities that may affect safety are established and conducted coherently for the protection of site personnel and the public, and protection of the environment.

4. EXECUTION OF THE SEVERE ACCIDENT MANAGEMENT PROGRAMME

4.1 In case of an emergency, in particular an emergency taking place in combination with an internal or external hazard, plant staff should assess the overall situation on the site and ensure that the emergency command and control structure is capable of directing the response in accordance with established guidance. If required, contingencies developed to re-establish the command and control structure should be implemented.

4.2 Once the staff of the main control room, while executing the EOPs, have reached the point of entry to the mitigatory domain, or the emergency director has determined that SAMGs should be applied, or the point of entry to SAMGs is reached by some other specified basis, the transition from the preventive domain (EOPs) to the mitigatory domain (SAMGs) should be made. The main control room staff should initiate actions under the SAMGs that apply until the responsibility for recommending actions is transferred to another appropriate structure, for example the technical support centre. This occurs when the technical support centre is operable and its staff are informed about the overall situation, have evaluated the plant status and are ready to give the first recommendation or decision on the execution of an SAMG. The main control room staff should continue to execute actions already initiated in the preventive domain, providing that they are consistent with the rules of usage of the SAMGs.

4.3 The technical support centre should reassess conditions at the plant at regular intervals as the accident progresses to confirm or adjust the priorities for mitigatory actions. Recommendations should be presented by the technical support centre in written form to the decision maker, who will decide on the course of actions to be taken. Records should be kept of all recommendations made.

4.4 Decisions on actions to be taken should be given to the control room staff in a form that minimizes misunderstandings. The main control room staff should confirm the actions they are being directed to take and should report back the progress of the actions taken and the impact that these have on the plant. Oral communication (by telephone or other suitable means) with the main control room staff and the supplementary control room staff should preferably be carried out by a staff member of the technical support centre who is a licensed operator. Prior to recommending or attempting to execute any action, the feasibility of the proposed action should be checked considering the allowable time frame for the action to be effective.

4.5 Essential plant parameters should be displayed in the main control room and in the technical support centre in an easily accessible way, e.g. by optical means (displays) or on a wall board, and in a manner that ensures that long term station blackout will not lead to loss of data. Trends should be noted and recorded. Actions taken should also be recorded, as well as other relevant information, such as the EOP or SAMG applicable at the time, emergency alerts for the plant and the planned releases of radioactive material. Adequate technical means should be provided for the recording of actions.

4.6 The timing and magnitude of possible future releases as a consequence of SAMG actions, such as planned releases, or their failure, and the possible release paths, should be estimated at regular intervals, and should be communicated in a suitable form through proper channels to external organizations responsible for further actions.

4.7 The work at the technical support centre should be well structured and based on a clear task description for each staff member. The staff of the technical support centre should convene in sessions at regular times, which should still permit sufficient time for individual staff members to perform their duties between these regular sessions.

4.8 The staff responsible for execution of accident management measures should be adequately qualified and adequate in number, in accordance with the evolving accident.

4.9 The on-site emergency director should ensure that external organizations are aware of planned actions with potential impact on the plant surroundings. Through consultations it should be ensured that off-site response organizations are aware of and prepared for planned releases of radioactive material.

4.10 A mechanism should be put in place to assign priorities in case of a conflict between planned releases and the off-site preparedness. In principle, priority should be assigned to the actions that address imminent threats to the integrity of the final fission product barrier such as the containment, and to avoiding containment bypass.

4.11 The process for decision making should take into account the fact that decisions may have to be taken within a very short time frame. In principle, the decision making process should match the time frame of the evolution of the accident.

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ANNEX I
Examples of the Implementation of SAMGs in Nuclear Power Plants

FRANCE

A-1. In France, the SAMGs applicable to the Électricité de France (EDF) nuclear fleet are set out in a ‘guide d'intervention en situation d'accident grave (GIAG)[14]. This has been developed in the form of both flowcharts and text. Two parameters are used for entry into GIAG, one characterizing a very high core exit temperature, and the other high containment activity.

A-2. Either criterion can be used for entering GIAG and subsequently performing a whole set of immediate actions by the staff of the main control room.

A-3. Upon entering GIAG, EOPs are exited. However, some specific actions that are called upon by EOPs and are beneficial for severe accident management may remain operational (e.g. containment venting). The possibility of some recommended actions leading to negative consequences is addressed from two different perspectives:

- For immediate actions, the balance between the pros and cons has been made during the development of the programme and it is considered that they can be implemented without undue risk.
- On the contrary, delayed actions must be evaluated by the crisis team when the accident is developing, and decisions have to be made after balancing the pros and cons of such actions. For each action that can possibly be considered, the pros and cons are provided in GIAG in order to allow response teams to make an informed decision.

A-4. Upon entering GIAG, emergency response teams prioritize actions to be implemented, the first priority being to minimize releases to the environment. In case an action is not successful, GIAG proposes alternatives to specialists in the technical support centres. In the case of unconventional development of the situation, emergency response teams are also allowed to propose to the emergency director, for approval or rejection, actions they consider appropriate for dealing with the identified development.

A-5. GIAG does not consider any pre-defined long term provisions nor does it incorporate exit criteria for the long term measures. Long term provisions are to be decided

[14] The terminology used in the examples is based on the specific terminology used in each State.

by emergency response teams. In relation to the long term operation of Generation II PWRs, strategies with specific provisions for long term management after a severe accident are being developed by EDF.

A-6. The importance of obtaining reliable information on capabilities or performing actions that are helpful for protecting the third barrier is recognized. Examples of such information or actions are:

- The Use of computational aids available for supporting the diagnosis of the plant status and informing the decision making process and the prognosis for evolution of the accident;
- The immediate opening of all safety relief valves (if not already open)[15] for preventing failure of the reactor pressure vessel at high pressure and limiting the risk of dispersal of debris in the upper parts of the containment (and potential subsequent direct containment heating in the case of failure of the reactor pressure vessel);
- Limiting the risk of re-pressurization of the reactor coolant system above 20 bars, before vessel failure, through specific limitations on water injection into the reactor coolant system;
- Limiting the risk of consequential steam generator tube rupture that would lead to containment bypass through immediate actions implemented upon entering GIAG, as follows:
  - Isolating radioactive steam generators;
  - Filling non-radioactive steam generators with water;
  - Depressurizing the reactor coolant system;
- Detection of failure of the reactor pressure vessel using temperature measurement in the reactor pit, with the potential for confirming the information by cross-checking other sources of information;
- Injection of water into the core with the objective of limiting the core degradation or cooling the molten core;
- Activation of the containment spray system to prevent over-pressurization of the containment and to remove thermal energy from the containment atmosphere;[16]
- Use of passive autocatalytic recombiners for eliminating hydrogen from the containment atmosphere;
- Heating of the pipe situated between the intake of the sand bed filter inside the

[15] In the case of the European Pressurized Reactor, additional dedicated valves are provided for this purpose.

[16] Activation of the containment spray system may be requested by the emergency response team when deemed appropriate (essentially for preventing unacceptable de-inertization of the containment atmosphere); it also leads to the flooding of the reactor pit.

containment and the containment filter for preventing steam condensation in the tube and in the filter.[17]

GERMANY

A-7. In Germany, although emphasis has been put on the prevention of severe accidents, hardware modifications were put in place and EOPs were developed after the Chernobyl accident; such measures included, in particular:

- The installation of filtered containment venting;
- The installation of passive autocatalytic recombiners on PWR units;
- Implementation of containment inertization on BWR units.

A-8. The development of SAMGs was started in 2010 and was fully completed at the end of 2014.

A-9. The SAMGs for PWRs are set out a severe accident management manual (SAM-M), which includes:

- The diagnosis of the plant damage state;
- Related strategies for mitigating the consequences of a severe accident;
- Detailed sheets of instructions for all measures within the strategies;
- Links to EOPs that are relevant for mitigatory strategies.

A-10. SAM-M is managed using clear criteria in an accident management flow chart. There are two entry criteria to SAM-M for at-power states. For shutdown states, an additional dedicated criterion is used.

A-11. Upon entering SAM-M, all EOPs remain active. In other words, after entering the SAM-M, EOPs in use remain active until a request for their interruption or termination has been issued.

A-12. In a severe accident, the plant state has to be diagnosed on the basis of the available instrumentation. In currently operating plants, there is no dedicated instrumentation for diagnosing in a simple way the status of the containment or the extent of core damage. Therefore, the data provided by the available post-accident instrumentation are used.

A-13. To prioritize measures for preventing massive core damage and failure of the reactor pressure vessel, the level of core degradation needs to be known. Three core degradation states are used for this purpose:

[17] For limiting the risk of hydrogen combustion in very specific situations.

- Core state A characterizes a low degradation level (the core still has a rod-like geometry);
- Core state B characterizes ongoing core degradation until failure of the reactor pressure vessel;
- Core state C means the reactor pressure vessel has failed.

A-14. Core states A and B are practically indistinguishable by means of measurements. Therefore strategies are implemented to apply for both states (‘A/B strategies’). However, strategies are robust in a sense that no harmful consequences will arise from using A/B strategies when failure of the reactor pressure vessel is not detected immediately (i.e. core state C has been reached).

A-15. Characterization of the confinement status or identification of the containment damage state is also made using a selection flowchart. For PWRs in Germany, six representative containment damage states have been defined:

- The containment is intact and there is no obvious risk of losing containment integrity;
- The integrity of the containment is challenged;
- The containment is bypassed to the secondary side of the steam generators;
- The containment is bypassed to the reactor building annulus;
- The containment is bypassed to the nuclear auxiliary building or the isolation of the containment has failed;
- The containment has been impaired (leak or rupture).

A-16. On the basis of these plant damage states, dedicated strategies are implemented to prioritize the performance of adequate mitigatory measures. Although the parallel execution of several measures is not excluded, the performance of previously initiated more efficient measures (measures with a higher level of priority) is not to be jeopardized. In addition, it is not recommended to postpone the initiation of measures having a lower level of priority until the success of previously implemented measures has been recognized.

A-17. When a high level action has been started, the emergency response team goes to the next high level action considered in the flow chart without the need to evaluate whether previously implemented actions are successful. To recognize any transition between different plant damage states (see para. A-15), the emergency response team regularly checks the parameters that define the plant damage states in order to determine whether the implemented actions have been successful or not. When applicable, conditions and criteria for terminating certain measures or effectiveness are given in the detail sheets. In case of a change of plant damage state, the implementation of the current strategy must be stopped and the execution of the new strategy starts from the beginning. However, all measures currently in execution will not be terminated until termination is explicitly demanded in the new strategy.

A-18. For all candidate high level actions, dedicated information is provided. In particular, the cons of implementing a specific measure are listed to allow the emergency response team to make an informed decision on what needs to be done. Implementation is recommended only after balancing pros and cons, and having reasonable assurance that the pros exceed the cons. If this is not the case, the emergency response team would not advise implementation of the planned action.

A-19. The SAM-M neither considers implementation of pre-defined long term provisions nor establishes any exit criterion for long term measures.

A-20. The importance of obtaining reliable information on capabilities that are helpful for protecting some of the barriers or performing actions that would also protect such barriers is recognized. Examples of such information or actions allowing the second barrier or the third barrier to be maintained are the following:

- Computational aids used for supporting the diagnosis of the plant damage state, the decision making process and the prognosis on the evolution of the accident, including the determination of the required flow for removing decay heat from the core.
- Rapid depressurization (i.e. in any case, opening of all pressurizer valves) of the reactor coolant system for preventing high pressure core melt that could lead to failure of the reactor pressure vessel and subsequent transfer of core debris to the upper parts of the containment with a potential risk of direct containment heating. This however would not prevent temporary re-pressurization of the reactor coolant system under some specific plant conditions.
- Prevention of bypass sequences resulting from steam generator tube rupture that has occurred as a consequence of isolating in advance dry steam generators that would likely be impossible to feed during the accident.
- Mitigation of the effects of steam generator tube rupture through isolation of all failed steam generators or by injecting water into failed non-isolated steam generators.
- Monitoring parameters that allow confirmation that the reactor pressure vessel has not failed, determining a minimum grace period by deterministic analyses before failure of the reactor pressure vessel and trending parameters that could allow characterization of failure of the reactor pressure vessel. For cases where the

differentiation between different core states cannot be done using existing instrumentation only, alternate means, such as computational aids can be used.

- Water injection into the reactor cavity (via the reactor coolant system) for preventing or limiting basemat attack and scrubbing fission products in case of failure of the reactor pressure vessel.
- Use of a flammability diagram for evaluating the risk of losing containment integrity in case of flammable mixtures, and recommending tripping of the containment heat removal systems when measurements indicate that the concentration of hydrogen inside the containment is nearing the flammability limit.
- Inertization of the filtered venting system for preventing its degradation.

UNITED STATES OF AMERICA

A-21. Operating plants in the United States have been developed by at least four vendors, namely Westinghouse, Babcock and Wilcox, Combustion Engineering and General Electric (GE). The first three vendors are PWR vendors, while GE is the sole vendor of the BWR technology in the United States. This has led to the development of four different approaches to the development SAMGs, and, although all PWR operators are now members of a single owners' group, the Pressurized Water Reactors Owners' Group, there is no unique approach for PWRs at this time. However, the Pressurized Water Reactors Owners' Group is in the process of developing a generic approach that will be used for all PWR operators as a basis document for their individual SAMGs. The generic PWR approach will be modelled after the Westinghouse version of SAMGs.

A-22. After entry into the mitigatory domain, Westinghouse plants rely on two logic diagrams, one relating to immediate severe challenges to the integrity of fission product barriers and ongoing releases, and a second logic diagram for following a certain chronology of anticipated challenges to fission product barriers. The other two PWR vendors rely on logic diagrams to establish plant damage states according to the technical basis report of the Electric Power Research Institute.

A-23. Once the mitigatory domain has been entered, all EOPs are exited, except in the case of Combustion Engineering plants, where EOPs and SAMGs are executed in parallel. However, in the approach retained by Westinghouse and GE plants, some important actions required in EOPs can be continued, but SAMGs have priority over EOPs. In the approach in Babcock and Wilcox plants, no re-entry into EOPs is considered. The SAMGs of all PWR plants address the pros and cons of expected actions, with a level of detail adapted to their needs. Westinghouse plants have adopted tables with the pros and cons of each expected action, and possible ways for mitigating the consequences of cons, while Combustion Engineering and Babcock and Wilcox plants have opted for including cautions in each guide.

A-24. For PWRs, priorities for implementing strategies or actions are given in a logic diagram, with an answer to a question in a logic diagram being always linked to an earlier question, but implementation of an action does not necessitate full completion of previously implemented actions. For BWRs, all SAMGs relating to core and containment behaviour are executed in parallel. When an action fails, only Westinghouse SAMGs provide alternatives.

A-25. There are no predefined long term provisions. Westinghouse SAMGs provide some exit conditions based on core exit temperature, primary pressure, containment pressure, hydrogen concentration and releases.

A-26. The importance of obtaining reliable information on capabilities that are helpful for protecting some of the barriers or of performing actions that would also protect such barriers is recognized. Examples of such information or actions for protecting the second barrier or the third barrier are:

- All PWRs use computational aids, while BWR plants treat this in technical support guidelines;
- Graded depressurization is not considered, except in the most recent version of the BWR SAMGs , which mention slow depressurization as a means for allowing an injection system using a steam turbine (the reactor core isolation cooling system) to run as long as possible through using reactor steam;
- Injection of water into the steam generators (this is the first priority for Westinghouse plants) or into the core (other PWR plants and BWR plants);
- Injection of water into the reactor cavity (common to PWR and BWR plants);
- Monitoring parameters that allow confirmation that the reactor pressure vessel has not failed (for Combustion Engineering and Babcock and Wilcox plants), and using logic diagrams to characterize vessel failure (Westinghouse plants have no such diagrams);
- Use of a flammability diagram for evaluating the risk of losing containment integrity in case of flammable mixture (used at all PWR plants, with various degrees of sophistication). For BWR plants, on the contrary, the issue is addressed in technical support guidelines. Hydrogen risk in venting system filters is not addressed as filtering is not considered in these systems.

JAPAN

A-27. The Japan Nuclear Regulation Authority requires licensees to develop severe accident management measures and to design systems, structures and components for preventing and mitigating severe accident, taking into account lessons from the Fukushima Daiichi nuclear power plant accident.

A-28. The following describes the outline of chapters 1 to 3 of new regulatory requirements for severe accident measures for light water nuclear power plants.

Chapter 1: Requirements for severe accident measures (major systems used for each measure)

(1) Common basic requirements on the equipment for use in severe accident management:

- Capacity:
  - Equipment for use in severe accident management shall[18] be designed to have sufficient capacity to cope with postulated beyond design basis accidents.
  - Mobile equipment for use in severe accident management shall be designed to have sufficient capacity with suitable margins in accordance with the necessary equipment reliability to cope with postulated beyond design basis accidents.
- Environmental and load conditions:
  - Equipment for use in severe accident management shall be designed to function as required with sufficient reliability under environmental and load conditions during postulated beyond design basis accidents.
- Operability:
  - Equipment for use in severe accident management shall be designed such that its operation is ensured under the conditions during postulated beyond design basis accidents.
- Diversity:
  - Permanent equipment for use in the preventive domain in severe accident management shall be so designed that diversity is considered as much as possible in respect of equipment for management of design basis accidents.
  - Mobile equipment for use in the preventive domain in severe accident management shall be as diverse as possible in respect of equipment for management of design basis accidents and permanent equipment for use in the preventive domain of severe accident management.
- Prevention of detrimental impacts:
  - Equipment for use in severe accident management shall be installed so as not to cause any detrimental impact on other equipment.
- Ease of changeover:
  - Equipment and procedures shall be prepared so as to allow easy and reliable changeover from normal line configurations in the event that other equipment is to be used for severe accident management, different from its original use.
- Reliable connections:
  - Measures shall be taken to standardize connecting methods to ensure that mobile equipment and permanent equipment for severe accident management can be easily and reliably connected and that such equipment can be used

[18] The use of 'shall' in this annex is to be understood to imply a national regulatory requirement rather than a safety requirement of the IAEA.

interchangeably between systems and units. Furthermore, multiple connections shall be prepared with appropriate spatial dispersion to avoid disconnection due to common mode failure.

- Seismic and tsunami resistance:
    - Appropriate measures for equipment for us in the mitigatory domain in severe accident management (including piping, valves and electrical cables within the building, in addition to connections to mobile equipment for use in the mitigatory domain in severe accident management) shall be taken in respect of procedures so as not to damage the necessary functions for withstanding standard ground motion and standard tsunami.
    - Equipment for use in the preventive domain in severe accident management (including piping, valves and electrical cables within the building, in addition to connections to mobile equipment for use in the preventive domain in severe accident management) shall have the equivalent seismic and tsunami resistance as the equivalent equipment for management of design basis accidents.
- Storage locations:
    - Mobile equipment for use in severe accident management shall be stored dispersed in different locations that are not easily impacted by external events (e.g. earthquakes, tsunami). Mobile equipment for use in severe accident management shall be stored in different locations from permanent equipment for use in severe accident management.
- On-site working conditions:
    - The locations of equipment for use in severe accident management shall be selected in such a way that the installation, connection, operation and recovery of mobile equipment for use in severe accident management can be done even in the event of a postulated beyond design basis accident, by, for example, selecting a suitable place that would not be affected severely by the accident, or by reinforcing the shielding performance.
- Securing access routes:
    - Access routes shall be designed and managed effectively so as to ensure the availability of required access routes on the site needed to transport mobile equipment for use in severe accident management or to inspect the damage of equipment under the postulated environment.
- Prohibition of shared use:
    - In principle, permanent equipment for use in severe accident management shall not be shared by more than two units. However this rule shall not apply if risks can be reduced and no other detrimental impact is caused by sharing the equipment.

(2) Preparation of procedures, implementation of drills and development of organizational systems:

- Appropriate organizational systems shall be established in advance by the formulation of the procedures and the implementation of drills in order to manage beyond design basis accidents rapidly and flexibly.

(3) Preparation of equipment and procedures for the following measures;

- Measures for reactor shutdown;
- Measures for cooling the reactor at high pressure;
- Measures for depressurizing reactor coolant pressure boundaries;

- Measures for cooling the reactor at low pressure;
- Measures for securing the ultimate heat sink for severe accident management;
- Measures for cooling, depressurization and reduction of radioactive material in the atmosphere of the containment vessel;
- Measures for preventing failure of the containment vessel due to overpressure;
- Measures for cooling molten core fallen to the bottom of the reactor pressure vessel;
- Measures against hydrogen explosions inside the containment vessel;
- Measures against hydrogen explosions inside the reactor building and other locations;
- Measures for cooling, shielding and maintaining the sub-criticality of spent fuel storage pools;
- Measures for securing make-up water and water sources;
- Measures for securing power sources for the following:
    - Control room;
    - Emergency response centre;
    - Instrumentation devices;
    - Radiation monitoring facilities;
    - Communications devices;
- Measures for suppression of off-site releases of radioactive material.

Chapter 2: Accident management for external events beyond the design basis

(1) Accident management with mobile equipment:

- Procedures shall be prepared for the following activities and measures for situations in which the plant has suffered large scale damage due to a large scale natural or human induced external event. Furthermore, organizational systems and the necessary equipment enabling these activities in accordance with the procedures shall be prepared.
    - Activities to extinguish a large scale fire;
    - Measures to mitigate fuel damage;
    - Measures to mitigate failure of the containment vessel;
    - Measures to minimize the release of radioactive material;
    - Measures to maintain necessary water levels and measures to mitigate fuel damage in spent fuel storage pools.

(2) Establishment of a specialized safety facility:

- The term 'specialized safety facility' refers to a facility with the function of suppressing a large release of radioactive material caused by failure of the containment vessel in the event of severe core damage or an almost damaged core as a result of a natural or human induced external event.
- The specialized safety facility shall be installed in accordance with the following:
    - The specialized safety facility shall be equipped with adequate measures for preventing the loss of necessary functions due to the intentional crashing of a large airplane into the reactor building.
    - The specialized safety facility shall be equipped with adequate measures for preventing the loss of necessary functions due to design basis seismic motion and

tsunamis.
  - The specialized safety facility shall be installed with equipment required to prevent failure of the containment vessel.
  - Equipment shall be designed so as to allow the use over a certain period of time.
  - An organization to maintain the functionality of the specialized safety facility shall be established.

Chapter 3: Evaluation of the effectiveness of measures for severe accident management

(1) Evaluation of the effectiveness of preventive measures against core damage and failure of the containment vessel:

- The licensee must postulate beyond design basis accidents that could cause severe core damage and prepare appropriate measures to prevent severe core damage.
- The licensee must postulate the failure modes of the containment vessel that could occur in conjunction with severe core damage and prepare appropriate measures to prevent failure of the containment vessel.

(2) Evaluation of the effectiveness of preventive measures against fuel damage in spent fuel storage pools.

(3) Evaluation of the effectiveness of preventive measures against fuel damage in a reactor during shutdown.