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Severe Accident Management Programmes for Nuclear Power Plants

DRAFT SPECIFIC SAFETY GUIDE
(DS483)

IAEA
INTERNATIONAL ATOMIC ENERGY AGENCY

FOREWORD
by Yukiya Amano Director General

EDITORIAL NOTE

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

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

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INTRODUCTION

BACKGROUND

1.1 This Safety Guide was prepared as part of the Agency's programme for establishing safety standards relating to nuclear power plants. It is a revision of the IAEA Safety Standards Series No. NS-G-2.15, Severe Accident Management Programmes for Nuclear Power Plants, issued in 2009, which is superseded by the present safety guide and is aimed at giving guidance on setting up an accident management program from the conceptual stage down to a complete set of procedures and guidelines. [Rephrased]

1.2 [Delete]

1.3 Accident management is the taking of a set of actions during the evolution of accident conditions with the objective of preventing the escalation of the event into a severe accident and mitigating the consequences of a severe accident, and achieving a long term safe stable state[1.] The second aspect of accident management is also termed severe accident management [1]. The return of the plant to the safe state is also called accident recovery. [Rephrased]

1.4 Accident management is an essential component of the defence-in-depth approach to prevent or mitigate the consequences of a severe accident [2-4]. [Rephrased]

1.5 An accident management programme comprises the preparatory measures, procedures and guidelines, equipment and human resources for preventing the progression of accidents, including accidents more severe than the design basis accidents, and for mitigating their consequences if they do occur [5]. [Rephrased]

1.5a To achieve the goal of establishing and maintaining a safe state, there are two different types of operating guidance documents for accident management referred to as emergency operating procedures (EOPs) and severe accident management guidelines (SAMGs). [new]

1.5b In line with the IAEA definitions [6], the purpose of EOPs is to guide the main control room staff and other emergency response personnel in preventing fuel degradation while making maximum use of all existing plant equipment including equipment that is not part of

[1] 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 indefinitely (see Ref. [1]).

plant systems for accident conditions. The purpose of SAMGs is to guide the Technical Support Centre (or equivalent) or crisis teams and the main control room during severe accidents. [new]

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

(1) Before the onset of fuel degradation, priority is given to preventing the escalation of the accident into a severe accident (preventive domain of accident management). In this domain, actions are implemented to stop accident progression before the onset of fuel degradation, or to delay the time at which significant fuel degradation happens;

(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 through;

- Maintaining the integrity of reactor pressure vessel[2] and containment;
- Performing any other actions to avoid or limit fission product releases to the environment and releases of radionuclides causing offsite contamination.

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

1.7 Accident management encompasses plans and actions undertaken to ensure that the plant and the personnel with responsibilities for accident management are adequately prepared to take effective onsite actions. The accident management programme needs to be well integrated with the emergency preparedness and response programme in terms of human resources, equipment, strategy and procedures. [Rephrased]

1.8 The accident management programme needs to consider all initial modes of operation before the accident, including combinations of events and failures that could cause failure of fuel cooling and ultimately significant radiological releases to the environment.

1.8a An accident management programme leads to the establishment of the necessary infrastructure to effectively prevent or mitigate severe accident conditions, prevent fuel degradation, and stabilize the unit if fuel degradation does occur. [separate from 1.8]

OBJECTIVE

1.9 This Safety Guide presents recommendations for the development and implementation

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

of an accident management programme for meeting the requirements for accident management that are established in relevant IAEA Safety Requirements for commissioning and operation in Sections 3 and 5 of Reference [4], design in Sections 2 and Section 5 of Reference [1], safety assessment in Section 4 in Reference [7] and emergency preparedness and response in Sections 2 and 3 of Reference [8].

SCOPE

1.10 This Safety Guide provides recommendations for the development and implementation of a severe accident management programme for a nuclear power plant, taking into account 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 (SSCs) to address Design Extension Conditions. For information on this topic refer to Section 5 of Reference [1]. [Rephrased]

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

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

STRUCTURE

1.13 This Safety Guide consists of four main sections and one annex. Section 2 presents the general, high level recommendations for an 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 for the execution of severe accident management guidelines are described in Section 4. Examples of severe accident management guidelines (SAMGs) implementation in different countries (France, Germany, the United States of America and Japan) are provided in the Annex I.

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

Subjective /Attribute	Preventive domain (prevention of progress to severe accident)	Mitigatory domain (mitigation of SA)
Objective	Prevention of fuel damage, through fulfilment of a set of safety functions of primary importance (‘fundamental safety functions’)	Limitation of release of radioactive material into the environment through actions comprising termination of core/fuel melt progression, maintenance of reactor pressure vessel integrity, maintenance of containment integrity, preventing containment by-pass and control of releases, and emergency response measures for minimizing radiological consequence.
Establishment of Priorities	Establishment of priorities among the various ‘fundamental safety functions’	Establishment of priorities between mitigatory measures, with the highest priority to mitigation of significant ongoing releases and immediate threats to fission product barriers
Responsibilities (authorisation of actions)	Main control room staff or emergency director if deemed appropriate.	Emergency director (or equivalent)
Role of emergency response organization	Technical support centre available for advice to main control room, or decision making for complex tasks, if deemed appropriate	Technical support centre (or emergency response facility) responsible for evaluation/recommendation of actions or providing decision making for complex tasks by operation support center, if deemed appropriate.

Procedures/ Guidelines	Use of procedures for preventive accident management measures (emergency operating procedures [EOPs]) by the main control room	Use of guidelines (severe accident management guidelines [SAMGs]) by Technical Support Centre or other designated organization
Use of equipment	Use of all systems available and non-permanent (e.g. mobile or portable), also use of margins admissible, advice or instructions by the technical support centre[3]	Use of all systems still available and alternatives (i.e. non-permanent equipment) to ensure fundamental safety function, also beyond their design limits, with preference given to safety features for design extension conditions, 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 to be considered in advance and monitored throughout and after implementation of measures unless such actions are to prevent or mitigate a severe challenge to containment integrity and immediate action is required per Severe Accident Management Guidelines (SAMG).”

[3] Some member states require that any decisions can be taken only by the authorized person (e.g. called the accident management chief in Russia Federation). All others can only provide information and advice to this person.

GENERAL GUIDANCE FOR THE ACCIDENT MANAGEMENT PROGRAMME

REQUIREMENTS

2.1 [Delete]

2.2 Requirement 19 on accident management in the operation of nuclear power plants in Reference [5] requires that "the operating organization shall establish, and shall periodically review and as necessary revise an accident management programme".

2.3 Paragraph 2.10 on safety in design in Reference [1] requires that "measures 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". [Rephrased]

2.4 Paragraph 5.6 in Reference [7] requires that "the results of the safety assessment shall be used as an input for onsite and offsite emergency response and accident management". [Rephrased]

2.5 Requirement 1 in Reference [8] requires that "an integrated and coordinated emergency management system for preparedness and response for a nuclear or radiological emergency is established and maintained. It is also required that the on-site emergency response to be promptly executed and managed without impairing the performance of the continuing operational safety and security functions both at the facility and at any other facilities on the same site" in Paragraph 5.2. [Rephrased]

2.6 Requirement 46 in Reference [9] requires that "as part of overall emergency preparedness and response arrangements are in place for the transition from an emergency exposure situation to an existing exposure situation"[4].

[4] Defined as situation of exposure that arises as a result of an accident a malicious act, or from any other unexpected event and require urgent action in order to avoid or to reduce adverse consequences. For the purpose of protection, the International Commission on Radiological Protection (ICRP) recommended reference levels for

CONCEPT OF ACCIDENT MANAGEMENT PROGRAMME

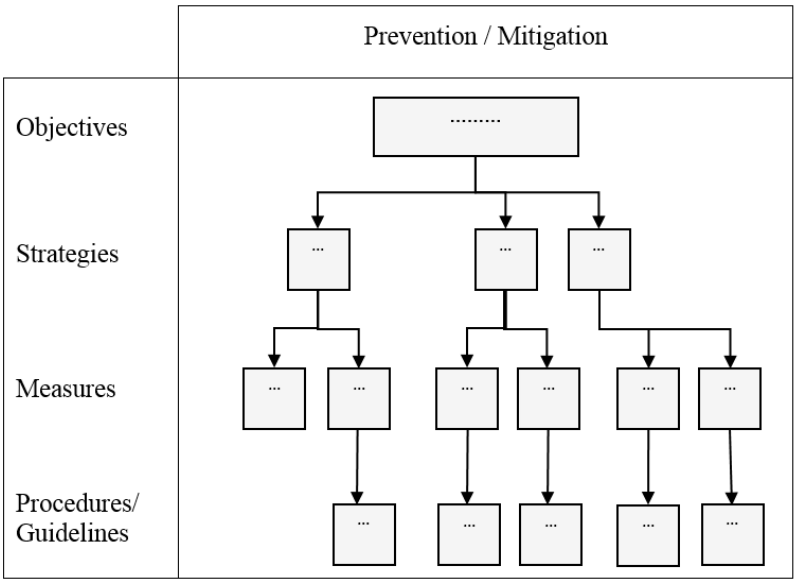
2.7 An accident management programme should be developed and implemented for prevention and mitigation of accidents irrespective of the core damage frequency and fission product release frequency.

2.8 The accident management programme should address all modes/states of operation and fuel locations, including spent fuel pool, taking into account possible combinations of events that could lead to accident conditions. It should also consider extreme external hazards[5] that could result in significant damage to the infrastructure onsite or offsite.

2.8a For a multi-unit nuclear power plant site where several units are co-located, the accident management programme should consider concurrent severe accidents on multiple units. [new]

2.9 An accident management programme should be developed and maintained consistent with the plant design and its current configuration.

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.



emergency exposure situations should be set in the band of 20–100 mSv effective dose (acute or per year) [23].

[5] Extreme external hazard is defined as an external hazard of levels exceeding those derived from the site hazard evaluation and considered for design.

Figure 1 Top down approach to accident management

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

- Preventing or delaying the occurrence of fuel degradation;
- Terminating the progress of fuel degradation once it has started;
- Maintaining the integrity of reactor pressure vessel to prevent melt through;
- Maintaining the integrity of the containment and preventing containment by-pass;
- Minimizing releases of radioactive material from the core or at other locations where radioactive material release could occur;
- Returning the plant to a safe state, where fundamental safety functions can be ensured.

2.12 From the strategies, suitable and effective accident management measures should be derived corresponding to available plant hardware provisions. Such measures may include plant modifications where these are deemed important for managing accidents including severe accidents. Personnel actions initiated either in the main control room or local actions could be an important part of these measures. During an accident such measures would include the use of systems and equipment still available, recovery of failed equipment and use of non-permanent equipment[6], stored onsite or offsite.

2.13 [Moved to 4.7a]

2.14 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) and preferably used in the mitigatory domain of accident management), should be developed from the strategies and measures for the personnel responsible for executing accident management activities.

2.15 Accident management guidance should assist plant personnel to prioritize, monitor, and execute actions in the harsh environments that may exist during accidents including those resulting from external hazards which are more severe than design basis external events.

[6] Non-permanent equipment is portable or mobile equipment that is not permanently connected to a plant and is stored in an onsite or an offsite facility.

2.16 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. Care should be taken if the possible use of some systems beyond their originally intended function is foreseen in the guidance on accident management[7].

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

2.17 Interface with radioactive waste management for intermediate remediation of contaminated areas during and/or after accidents should be considered appropriately for staff or workers to access certain areas for performing local accident management actions [12].

2.18 Interfaces between safety and security should be managed appropriately throughout the lifetime of the facility 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 if they occur [13].

MAIN PRINCIPLES

2.19 Accident management guidance should be developed for all identifiable mechanisms that could challenge fundamental safety functions or boundaries to radioactive materials release to minimize the impact on public health and safety regardless of their probabilities of occurrence,

2.19a Accident management guidance should be an integral part of the overall emergency arrangements and be coordinated with the plant's Emergency Plan. This should include lines of responsibility and accountability for implementing response actions during execution of accident management guidance to maintain or restore safety functions throughout the duration of the accident. [Moved from 2.20]

2.19b Accident management guidance should be robust, which can be assured by the following:

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[7] Some member states require legal or regulatory requirements that prevent using some systems beyond their originally intended function or design basis. In this case, advance consideration is given to modification of operational policies and/or principles and the NPP licensing framework to permit usage of key systems beyond their design basis such that legal flexibility can be provided to the operating organization for severe accident prevention and mitigation.

(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 severe accident conditions;

(3) It should implement all feasible measures that will either maintain or increase the margin to failure or gain time prior to the failure of safety functions or fission product barriers;

(4) the possibility of adding components, including non-permanent equipment, should be investigated in the event that existing plant systems are unable to preserve fundamental safety functions or limit challenges to fission product barriers for conditions not considered in the design;

(5) Consideration of plant conditions in shutdown modes particularly when the containment barrier is temporarily not available or there is the difficulty to add water for decay heat removal. [Moved from 3.26]

2.19c Accident management guidance should consider that plant conditions at which the transition is to be made from prevention to mitigation should be specified and should be based on defined and documented criteria. [Moved from 2.25]

2.19d Accident management guidance should address the full spectrum of events, including credible and relevant internal and external hazards. Possible complications during their evolution that could be caused by additional hardware failures and human errors. [Moved from 3.3]

2.19e External hazards should be considered with hazard exceeding the magnitude established in the site evaluation and/or its equivalent to a mean annual frequency exceeding the probability of accidents established in the design for the plant.[8]

2.20 Accident management guidance should also consider that in case of extreme external hazards, there may be extensive infrastructure damage, so that offsite resources are not readily available, examples include human resources and/or communication, electrical power, transportation, availability of spare parts, lube oil, compressed air, water and fuel.

2.20a Contingency measures such as alternative supply of water, compressed air or other gasses and mobile electrical power sources should be located and maintained as to be functional and readily accessible when needed.

[8] For example, at least one order of magnitude in Canada

2.21 Accident management guidance should be considered for any specific challenges posed by shutdown plant configurations and large-scale maintenance. The potential damage of fuel both in the reactor core and in the spent fuel pool, and 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 accident management should be the safety of the workforce (staff).

2.21a Accident management guidance should include equipment and supporting procedures necessary to respond to accidents that may affect multiple units on the same site and last for extended periods. Personnel should have adequate skills for using such equipment and implementing supporting procedures and adequate multi-unit emergency organization staffing plans should be developed. [Separated from 1.8]

2.22 [Moved to 2.19b].

2.23 The utility or licensee should have full responsibility for implementation of the accident management guidance and take steps to ensure that roles of the different members of the onsite emergency response organization involved in accident management have been clearly defined, allocated and coordinated.

2.24 Adequate staffing and working conditions (e.g. acceptable radiation levels, elevated temperatures and humidity, lack of lighting, access to plant from offsite) should be considered for managing accidents, including those resulting from extreme external hazards. Accident management should consider that some events may result in similar challenges to all units on the site. Therefore plans for defining staffing needs 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 provide alternate personnel to fill the corresponding positions in case of unavailability of staff.

2.25 [Moved to 2.19c]

2.26 The accident management programme should be periodically reviewed and revised where appropriate to reflect the changes of plant configuration, operation experience, major lessons learned and new results from relevant research.

2.27 The approach in accident management should be, as far as feasible, based on either directly measurable plant parameters or information derived from simple calculations and should consider the loss or unreliability of indication of essential plant parameters that has not been designed against extreme external hazards.

2.28 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.

2.29 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 parameter levels and at a time that gives sufficient confidence that the goal intended to be achieved by carrying out the action will be reached

2.29a The accident management guidance should be efficient for time-constraint actions (e.g. reactor coolant system depressurization, containment isolation/venting). [new]

EQUIPMENT UPGRADES

2.30 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 accident management programme.

2.31 When addition or upgrade of existing equipment or instrumentation is considered, related design requirements should be such that there is reasonable assurance[9] that this equipment or instrumentation will operate as intended under the accidents including those originated by extreme external hazards. The operability of the considered equipment or instrumentation should be either demonstrated by equipment qualification or by assessment of the survivability.

2.32 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.

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

2.32a New equipment should be designed against accident conditions and for conditions arising from internal and external hazards commensurate with the intended function.

2.32b Equipment, either permanent, or non-permanent that is stored onsite or offsite, should be protected from postulated hazardous conditions including internal and external hazards that cause the challenge. For non-permanent equipment such as portable or mobile equipment, the ability to move the equipment from its storage location to the location where it fulfils its accident management function and to perform the necessary connections under the conditions existing during the accident and in the time frame needed should be verified.

2.32c Impact of the new or upgrading equipment on the staffing needs as well as expectations for maintenance and testing should be addressed. [Moved from 2.34]

2.33 The installation of new equipment or the upgrading of existing equipment to operate under harsh environmental conditions does not eliminate the need to develop accident management guidance for the situation when some of this equipment malfunctions.

2.34 [Moved to 2.32b].

FORMS OF ACCIDENT MANAGEMENT GUIDANCE

Preventive domain

2.35 In the preventive domain, the guidance should take the form of procedures, usually called emergency operating procedures (EOPs), which are prescriptive in nature. EOPs should cover both design basis accidents and design extension conditions without significant fuel degradation.

2.35a Further details on objective, scope, development and implementation of EOPs are given in References [6, 16]. [separate from 2.35 and rephrased]]

Mitigatory domain

2.36 In the mitigatory domain, large uncertainties may exist both in the plant status, availability of the systems and in the timing and outcome of actions. Consequently, the guidance for the mitigatory domain should distinguish between what can be prescriptive (because there is no doubt on benefits, for example reactor coolant system (RCS) depressurization on pressurized water reactor (PWR) and what cannot be prescriptive in nature. In the latter case, the guidance should include a range of potential mitigatory actions and should allow for additional evaluation and alternative actions. Such guidance is usually called severe accident management guidelines (SAMGs).

2.37 The guidance 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 support organization staff to reach timely decision on the actions to take during the evolution of the accident.

2.38 The guidance for the mitigatory domain should be presented in the appropriate form, including 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. used in the preventive domain. Manuals or handbooks typically contain a more general description of the tasks to be executed and their justification.

2.39 SAMGs should be designed with the appropriate level of detail and in a format that facilitates their effective use under stressful conditions. The usability of the guidelines (step-by-step instructions or flexible decisions) should be considered in the development process and be clear to the user.

2.40 The overall form of the guidelines and the selected level of detail should be tested evaluated during validation of the guidelines and then tested in drills and/or exercises. Based on the outcome of such drills and/or exercises, it should be judged whether the form is appropriate and whether additional detail should be included in the guidance. Drills and/or exercises should provide for identification of areas for improvement.

2.41 [Delete due to redundancy with 2.43a]

Both preventive and mitigatory domains

2.42 For situations that result in accident management arrangement for directing responses 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 onsite Emergency Response Organization, support procedures or guidelines may be developed on using instrumentation and equipment to cope with these conditions. The severe accident guidance should include conditions for use of these support guidelines.

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

2.43a The background documents should be used to support training of the Technical Support Centre staff on severe accident phenomenology, the basis for severe accident management guidance and the benefits and detriments of various postulated mitigating actions.

2.44 Hardcopies should always be available in all evaluation and decision making locations, such as the main control room, supplementary control room and 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 hazard. [Rephrased]

ROLES AND RESPONSIBILITIES

2.45 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 made. In the preventive domain, the main control room supervisor or a dedicated safety engineer or other designated official should be able to fulfil this responsibility. In the mitigatory domain, decisions should be made by person(s) having a broader perspective of accident management activities and understanding comprehensive implications of the decisions. Some member states require that the main control room supervisor has to be capable to perform works in any aspects of accident management until the person(s) authorized to manage emergency works starts to execute his duties.

2.45a Major decisions which could have significant adverse effects on public safety or the environment should be made with the full knowledge of the person entrusted with legal responsibility for the plant, where reasonably practicable.

2.46 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 response arrangements onsite and offsite, if appropriate.

2.47 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.

2.48 A specialized team or group of teams (referred to in the following as the Technical Support Centre) should be available to provide technical support by performing evaluations and recommending recovery actions to a decision making authority, both in the preventive and mitigatory domains. The Technical Support Centre should have the capability, based on their knowledge of plant status to recommend mitigatory actions as deemed most appropriate for the situation. This should be done only after evaluating potential consequences of such recommended actions and the possibility and consequences of using erroneous information. If the Technical Support Centre is composed of multiple teams, the role of each team should be specified.

2.49 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 deciding when to transition between domains.

DEVELOPMENT AND IMPLEMENTATION OF AN SEVERE ACCIDENT MANAGEMENT PROGRAMME

TECHNICAL BASES [change title]

3.1 Six main steps should be executed to set up and develop an severe accident management programme: [Rephrased]

(1) Identification of challenge mechanisms:

- Mechanisms that could challenge fundamental safety functions or boundaries to radioactive materials release should be identified;

(2) Identification of plant vulnerabilities:

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

(3) Identification of plant capabilities:

- Plant capabilities under challenges to fundamental safety functions and fission product barriers including capabilities to mitigate such challenges, both in terms of available equipment and personnel should be considered;
- Available or necessary hardware provisions for execution of accident management strategies should be considered;

(4) Development of accident management strategies and guidelines:

- Suitable severe accident management strategies and measures should be developed, including the use of permanent and onsite and offsite non-permanent equipment and instrumentation to cope with the vulnerabilities identified;
- Strategies 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, including cases in which information provided by instrumentation is erroneous and all normal instrumentation and control power is unavailable should be considered;

- 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;

(5) Establishment of verification / validation process:

- Verification and optimization of severe accident management strategies should be performed;
- Verification and validation of guidelines should be performed;

(6) Integration of accident management program into management system:

- Specification of lines of decision making, responsibility and authority in the teams that will be in charge of the execution of the accident management measures;
- Human and organizational factor aspects should be considered;
- Integration of the accident management programme within the emergency response preparedness arrangements for the plant should be considered;
- A systematic approach to periodic evaluation and updating of the guidance and training with incorporation of new information and research insights on severe accident phenomena should be considered;
- Education and training, drills and exercises and evaluation of personnel skills should be considered.

3.2 Consideration should be given to severe accident sequences, using a combination of engineering judgement and deterministic methods and probabilistic methods. Sequences for which reasonably practicable mitigatory measures can be implemented should be identified. Acceptable measures should be based upon best estimate assumptions, methods and analytical criteria. Activities for developing guidance for severe accidents should take into account the following:

(1) Operational experience, relevant safety analysis and results from safety research;

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

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

implementation;

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

- some systems beyond their originally intended function and anticipated operational states when the use of the systems may not make the situation worse;
- use of additional non-permanent systems/components, to return the plant to a safe 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;

(5) For multi-unit sites, consideration of the use of available means and/or support from other units provided that the safe operation of such units is not compromised.

3.3 [Moved to 2.19d]

IDENTIFICATION OF CHALLENGE MECHANISMS [new sub-title]

3.4 The selection of severe accident sequences should be sufficiently comprehensive to provide a basis for guidance for the plant and support personnel in any identified situation. Useful guidance can be obtained from the probabilistic safety assessment (PSA) Levels 1 and 2 [11, 12], from engineering judgment or similar studies from other plants, and internal and external experiences.

3.5 [Delete EOP scope]

3.6 Severe Accident Management guidelines for mitigatory domain 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 hazard, and possible consequential failures and physical phenomena that may occur during the evolution of a severe accident. In this process, even highly improbable failures should be considered.

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

3.7a In view of the inherent uncertainties involved in determining credible events, the PSA should not be used a priori to exclude accident scenarios from the development of severe accident management guidance If such use is considered, extremely low cut-off levels should be specified so as not to underestimate the scope and nature of scenarios to be analysed.

3.8 [Deleted redundancy with 3.7]

3.9 [Combine with 3.1]

3.10 Severe accident management programmes may be developed first on a generic basis by a plant vendor or plant designer organizations or other organization duly authorized by the operating organization and may then be used by a plant utility for development of a plant specific accident management programme. When adapting a generic severe accident management programme to plant specific conditions, care should be taken that the transition from a generic approach to a plant specific one is handled appropriately, including searching for additional vulnerabilities and strategies to mitigate these. Any deviations from plant operating requirements and generic severe accident management guidelines should receive a rigorous review that considers the basis and benefits of the original approach and the potential unintended consequences of deviating from this approach.

3.11 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 should be involved, with support from the upper management of the operating organization.

3.12 [Move to 3.69b]

3.13 [Move to 3.69c]

3.14 [Move to 3.69d

3.15 [Delete]

3.16 [Delete]

IDENTIFICATION OF PLANT VULNERABILITIES

3.17 [Delete redundancy phrase]

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

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

3.20 The vulnerabilities to postulated hazardous conditions including extreme external hazard that can impact the use of severe accident management features, both permanently installed as well as non-permanent should be identified. It should be investigated how specific hazards can interfere with the use of severe accident management features.

3.20a Vulnerabilities resulting from the failure of command and control structure due to loss of the main control room or impairment of the capability to set up the onsite Emergency Response Organization should also be addressed. (Moved from 3.19 separated second sentence)

3.21 The behaviour of the plant during severe accidents, including those 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 depending on actual plant conditions and timing of real events and decision makers should be cognizant of these differences. Symptom-based approach to severe accident management guidance should be preferred so that the decision makers can respond to actual plant condition and not make decisions solely based on stylized analytical results. [Rephrased]

3.22 [Deleted redundancy phrases in 3.7]

~~**Multi-unit sites**~~

3.23 [Move before 3.70a]

3.24 [Move before 3.70b].

IDENTIFICATION OF PLANT CAPABILITIES

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

3.25a When unconventional/alternative line-ups or hook-up connections has to be planned, consideration should be given to the availability of equipment necessary for easy use of these capabilities by the appropriate staff and to the restriction of unauthorized access to such equipment. [Separate from 3.25]

3.25b 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 instruction should be prepared in advance defining a set of steps that have been appropriately reviewed including the identification of pre-requisites (e.g., pre-staging of any special tools or components) necessary to take actions safely and quickly.

3.26 [Move to 2.19b]

3.27 The ability of plant personnel to successfully perform unconventional measures to mitigate accident challenges under adverse environmental conditions should be carefully considered. Where necessary protective means should be provided and training should be implemented for the execution of such tasks in conditions as realistic as possible, for instance using protective clothing and breathing equipment. It should be noted that work that poses risks to the health or the life of plant personnel is voluntary in nature and can never be demanded of the individual; the guidance should be developed accordingly. The procedures/instructions associated with such actions should contain a warning in the introductory section that defines the potential risk(s) to the health and safety of the procedure user(s), and any protective actions which should be taken.

3.28 The capabilities of the plant personnel to deploy mitigating equipment in possible harsh environments should include the implications of:

- Working in high temperature, pressure and humidity areas;
- Working in poorly lit or dark areas;
- Working in areas ventilated using portable ventilation systems;
- Working in high radiation areas;
- Wearing protective clothing and portable breathing gear;
- Use of non-permanent instrumentation or non-permanent power supplies.

DEVELOPMENT OF SEVERE ACCIDENT MANAGEMENT STRATEGIES AND GUIDELINES

Accident Management Strategies for Severe Accidents

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

3.30 [Delete prevent domain due to duplicated]

3.31 Strategies should be developed with the objectives of:

- Terminating the progress of fuel degradation in the reactor core and the spent fuel pool;
- Preventing re-criticality in the reactor vessel;
- Maintaining the integrity of the reactor vessel and the spent fuel pool;
- Maintaining the integrity of the containment or any other confinement of fuel and preventing containment bypass;
- Minimizing offsite releases of radioactive material;
- Returning the plant to a safe state where fundamental safety functions can be ensured.

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 reactor vessel failure and direct containment heating, flooding the reactor cavity to prevent or delay vessel failure and subsequent basemat failure, mitigating the hydrogen concentration, depressurizing the containment to prevent its failure by excess pressure or to prevent basemat failure under elevated containment pressure, etc. [17]. [Rephrased adding footnote]

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

3.33 Particular consideration should be given to 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 under a given plant damage condition.

3.34 Strategies should be prioritized taking into account plant damage status and the existing and anticipated challenges. The basis for the selection of priorities in accident management strategies should be:

- prevention of 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 mitigatory actions,
- maintaining the integrity of the containment as highest priority after reaching the entry conditions to the mitigatory domain.

3.34a When prioritizing, special attention should be paid to the following:

- Timeframes and severity of challenges to the barriers against releases of radioactive material;
- Availability of support functions as well as possibility of their restoration;
- Plant initial operating mode as accidents can develop in operating modes where one or more fission product barriers could already be lost at the beginning of the accident;
- 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 first priority when the fuel is undamaged and containment intact, while restoring 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);
- Difficulty of developing several strategies in parallel;
- Long-term implications or concerns of implementing the strategies.

3.35 For 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 fundamental safety functions taking into account possible adverse conditions onsite. Support items such as fuel for non-permanent equipment should be available.

3.35a Accident management strategies should be developed even for situations when DC power is lost after a long-term loss of all AC power. [Moved from 3.81]

3.36 The implementation of specific mitigatory strategies should be triggered either when certain parameters reach their threshold values or trends of significant parameters are observed such that reaching threshold values is imminent. These parameters should be selected to be indicative of challenges10 to fission product barriers.

3.37 If strategies are considered that need to be implemented within a certain time window the inherent uncertainty when determining the time should be taken into account in identifying such a time window. However, care should be exercised in order not to discard potentially useful strategies.

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

3.39 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 geometry or corium debris configuration should be maintained, and a path should be provided from the core or corium debris decay heat to an ultimate heat sink, where possible.

3.40 Strategies which avoid or minimise 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 accumulated contaminated water should be considered.

3.41 Strategies should be documented and maintained including those 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.

Severe Accident Management Guidelines

3.42 The strategies and measures in the previous section should be converted to guidelines for the mitigatory domain (SAMGs). Some plants also use procedures in the mitigatory domain especially in the early phase of a severe accident for actions initiated from the main control room before the technical support centre is functional. Guidelines should contain the necessary information and instructions for the responsible personnel to successfully

[10] For examples; large release at onset of accident; bypass of the containment; high Pressure Melt Ejection (HPME); core cooling, ultimate heat sink and RPV melt-through; hydrogen production and combustion; Molten Core Concrete Interaction (MCCI); containment pressurisation; containment sub-atmospheric pressure; release of fission product to the environment; spent fuel pool damages

implement the strategies, including the use of equipment.

3.43 Guidelines should be written in a predefined format using simple and consistent language and specific terms in accordance with established rules preferably in a writer's guide. Instructions in guidelines should be written be clear and unambiguous way so that implementers can be readily executed under high stress and time-constraint conditions. They 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). Also the available line-ups to achieve the injection should be identified and guidance should be put in place to configure unconventional line-ups, where these are needed. It should be known how long water sources will be available, and what needs to be done to either replace or to restore them once they are depleted. [Rephrased]

3.43a Severe accident management guidelines 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.

3.43b Severe accident management guidelines should not be adversely impacted following plant changes including plant modifications, operating procedure and training programme changes. (Moved from 3.1)

3.44 Human factor aspects should include consideration of; [Rephrased]

- the performance under the contextual and adverse boundary conditions given;
- command and control structure.

3.44a Command and control structure should be maintained, and alternate communication means among onsite area (such as emergency response facilities) offsite area, and headquarters of the operating organization, etc. should be ensured and confirmed through exercises and drills.

3.44b Development team should assess potential loss of command and control structure to develop associated guidance consideration of the following situations:

- Number of affected units (reactor core and spent fuel pools);

- Control facilities functionality and habitability;
- Damage to essential structures and buildings;
- Availability of AC and DC power required for operation of plant systems;
- Availability of access to essential buildings and equipment;
- Availability of operations personnel and site staff for implementation of procedure and guideline;
- Actions taken can be by non-licensed personnel, typically an auxiliary operator;
- Availability of other on-site control rooms and personnel in separated buildings;
- Capability to communicate within the plant emergency command and control structure and with offsite organisations.

3.45 Where accident conditions require immediate attention and short-term actions, there may be no time available for the deliberation of all possible consequences of the actions. In such cases the guidance should be developed accordingly by directly identifying the recommended action.

3.46 The severe accident management guidelines should contain as a minimum the following elements:

- Objectives / goals;
- Interface with EOP
- Initiation criteria;
- Potential negative consequences of the actions;
- Monitoring of strategies;
- Cautions and limitations;
- The equipment and resources (e.g. AC and DC power, water) required;
- Consideration of required personnel resources;
- Consideration of habitability for local action;
- Use of diagnostic tools and computational aids
- The time window within which the actions are to be applied;
- Local actions sheets (if applicable);
- Transition criteria and exit/termination conditions;
- Assessment and monitoring of plant response.

3.47 The set of guidelines should include design limit 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 severe accident management should be taken into account when developing guidelines. [Combine with 3.1]

3.47a Specific attention should be paid to situations where instrumentation is lost or incorrect due to a loss of power or harsh environment. Guidelines should be provided for making adequately informed decisions in such cases. [Separate with 3.47]

3.47b The important criteria for decision making such as containment venting or sea water injection into the reactor vessel should be incorporated into the guideline.

3.48 Guidelines 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 due to the evolution of the accident. Alternatively, the guidelines can be fully linked to the observed physical state of the plant so further diagnosis of the accident sequence is not necessary. The guidelines should be aimed at monitoring, preserving or restoring fundamental safety functions on the basis of the selected strategies. [Rephrased]

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

3.50 The guidelines should be developed in such a way that the potential for an erroneous diagnosis of plant status is minimized. The use of redundant and diverse instrumentation and signal is recommended. If there is no redundancy preference should be given to utilizing instrumentation designed to withstand the environmental conditions of the accident.

3.51 [Delete]

3.52 The guidelines should be written in such a way that there is a possibility to deviate from the recommended strategies where this might be necessary or beneficial.

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

3.54 Guideline sets that are implemented during severe accident conditions should be integrated with each other to establish a comprehensive strategy for severe accident management.

3.55 A transition point from the preventive domain to the mitigatory domain should be set with careful consideration of 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. 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 fuel temperature rise, the degree of fuel degradation as a consequence of anticipated time needed for identification of the transition point..

3.55a Protocols for communicating with various stakeholders 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.

3.56 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 operators in this case should be presented in a way that makes prompt and easy execution possible and, therefore should be presented in a format operators are able to work with and already trained for.

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

3.58 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 conflict.

3.59 In addition to entry conditions to the SAMGs exit conditions/criteria to long term provisions should be specified. A safe state should be clearly defined and provisions to maintain the safe state should be specified.

3.60 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 table) and/or pre-calculated graphs.

3.61 It should be noted that various equipment may start automatically or change configuration when certain parameters reach pre-defined values (‘set points’).Such automatic action 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 mitigative domain should be inhibited. Manual actions on the equipment concerned should then be considered in the guidance.

3.62 Guidelines should contain the preferred accident management equipment which is available. Alternate methods for achieving the same purpose should be explored and, if available, included in the guidance. For example, equipment failures include instrumentation failure or equipment lockout and finding the situation of equipment availability is part of plant operation.

3.63 Severe accident management guidance should include recommendations on the priorities for restoration actions. In this context the following should be considered:

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

3.64 The time to recover unavailable equipment or to implement/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.

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

3.65a When containment venting is considered or directed in the severe accident management, it is recommended to consider the followings in the guidance:

(1) Situations when all AC and DC power is lost and the instrument air system is not available;

(2) Situations involving high radiation areas and high temperatures in areas where vent valves are located (if local access is required);

(3) The potential negative consequences of containment venting should be assessed during the decision making process.

3.66 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 guidelines. Computer based aids should consider the limited battery life of self-contained computers (laptops) and the potential for loss of AC power.

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

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

3.68 Adequate background documentation material should be prepared to support development of severe accident management guidelines 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:

(1) 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;
- The detailed description and basis for steps in procedures and guidelines;

- The basis for specification of set-points used in the guidelines.

(2) It should provide basic material for training courses for accident management staff.

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

3.69a Potential changes to the SAMGs should first be made to the relevant background documents to ensure the changes are thoroughly evaluated. Such updated background documents and SAMGs should be issued to the operating organization simultaneously for validation and training.

3.69b The development team should contain staff responsible for the development and implementation of the severe accident management programme in the plant. The development team should ensure involvement from the training department, operations staff, maintenance staff, radiation protection staff, instrumentation and controls staff, engineering staff, persons responsible for emergency preparedness and response planning and external experts as appropriate. If use of a generic programme has been selected, experts familiar with this programme may support the development team. [Moved from 3.12]

3.69c The main control room staff including supplementary control room staff or Technical Support Centre staff or any other organizational unit staff 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 an accident management programme. [Moved from 3.13]

3.69d Consideration should be given to the way in which plant personnel will be made available to participate in the development activities of the accident management programme in relation to their normal duties. Sufficient time should be allocated to plant personnel associated with the development team in relation to their other obligations. [Moved from 3.14]

Severe Accident Management for Multi-unit Sites

3.70 In the case of multi-unit site with shared safety related equipment or systems, the continued use of a unit that has not been affected should be taken into account in the accident management guidance. Special care for exist plants should be used to identify 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. Sharing of support systems is an extended practice in old plants. The current IAEA safety standards for NPPs, SSR 2/1 (rev.1) require that each unit has its own safety systems and its own safety features for design extension conditions, including severe accidents. There should be pre-defined criteria to decide whether or not the operating units at the same site should be shut down.

3.70a For new plants, each unit of a multiple unit nuclear power plant should have its own safety systems and should have its own safety features for design extension conditions. (Requirement 33 and Para. 5.63). To further enhance safety, means allowing interconnections between units of a multiple unit nuclear power plant should be considered in the design.

3.70b Effectiveness of equipment and response centres (e.g. main control room and/or 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 on several units. [Moved and combined from 3.23, 3.24]

3.70c If structures, systems, and components (SSCs) which use is considered for severe accident management are shared with different unit(s) an assessment should be performed whether safe shutdown is achievable on the other unit(s).[moved from 3.24]

3.71 When there are reactors located at neighbouring site(s) in the near distance from the reactor in accident conditions sharing of information with neighbouring reactors should be considered for investigating whether expected dose rates and other environmental conditions due to radiological propagation from unit(s) in neighbouring site may affect access to the site.

3.72 The guidelines should address the possibility that more than one, or all units, may be affected, concurrently including simultaneous accidents including the possibility that damage propagates from one unit to other(s), or is caused by actions taken at one unit.

HARDWARE PROVISIONS FOR SEVERE ACCIDENT MANAGEMENT

3.73 For existing plants, changes in 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. Evaluation should include considerations of regulatory acceptance criteria or safety goals if they have been defined. [Rephrased]

3.74 For new plants, when additional equipment is provided to mitigate severe accidents, the latter equipment should preferably be independent from equipment and systems used to cope with design basis accidents. [Rephrased]

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

3.76 Equipment upgrades aimed at preserving the containment function, or minimizing releases when the containment function has been lost or by-passed should be considered as a high priority.

3.76a Equipment upgrades which increase capability or margin to failure for the following functions should be evaluated:

- Monitoring 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, airlocks, etc., 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 severe accidents;
- Monitoring and control of containment leakages and of fission product releases;
- Challenges, such as for;
  - reactor vessel melt-through;
  - basemat melt-through by molten corium;
  - corium – concrete interaction, leading to combustible gas production;
- Removing the produced heat from the corium debris to an ultimate heat sink.

3.77 [Combine with 3.76]

3.78 [Move to 3.84b]

3.79 [Delete due to redundancy with 3.80]

3.80 [Move to 3.65a]

3.81 [Move to 3.35a]

3.82 Additional hardware provisions should be considered including non-permanent onsite and offsite 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. [Rephrased]

3.83 Non-permanent equipment needed for accident management should be staged and protected so that it could be ready for use within a predefined timeframe.

3.84 When the strategies rely on non-permanent equipment, the equipment survivability for anticipated conditions, configuration and layout should be assessed whether they are 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.

3.84a The non-permanent equipment should be diversely located to the extent practicable so as to avoid common cause failures due to external hazards such as earthquake and tsunami.

3.84b For non-permanent equipment multiple hook-up points to facilitate their use during external hazards should be considered taking into account benefits versus potential negative implications.

3.85 Maintenance, testing and inspection procedures should be developed for equipment including non-permanent equipment to be used in severe accident management.

For multi-unit sites

3.85a Where equipment (including both permanent and non-permanent) is installed for use in severe accident management, there should be consideration that severe accidents can occur simultaneously on more than one unit.

3.85b 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 unit(s).

INSTRUMENTATION AND CONTROL FOR SEVERE ACCIDENT MANAGEMENT

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

3.86a A strategy for alternate information source should be prepared when the plant parameters derived from instrumentation are not reliable.

3.86b A strategy for disconnecting non-essential battery loads should be prepared beforehand to extend battery life until such time as the battery can be recharged or alternate power source provided

3.87 Guidance should be provided to validate important instrumentation outputs (i.e., those 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. This should also be emphasized in drills and exercises.

3.88 [Merged with 3.47]

3.89 [Redundancy with 3.86]

3.90 All available information and background documentation on essential instrumentation needed to support accident management decision making should be available to appropriate members of the emergency response teams.

3.91 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.

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

- Use of instrumentation that is designed for the expected environmental conditions following an accident should be the preferred method to obtain the necessary information;
- Alternate instrumentation should be identified if the preferred instrumentation

becomes unavailable or not reliable.

Where such instrumentation is not available, additional means (such as computational aids), or alternate strategies should be developed.

3.93 The effect of environmental conditions on the instrument reading should be estimated taking into consideration of a local environmental condition which can deviate from global conditions because 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 accident conditions should be identified.

ANALYSES FOR DEVELOPMENT OF SEVERE ACCIDENT MANAGEMENT PROGRAMMES

3.94 [Delete]

3.95 Development and implementation of the accident management programme should be supported by appropriate computational analysis showing progression of representative accident scenarios to be addressed by accident management with the results to be used for formulation of the technical basis for development of strategies, procedures and guidelines. The results of accident analysis should assist to: [Rephrased]

- specify the criteria that would indicate the onset of severe core damage;
- identify the symptoms (i.e., parameters and their values) by which staff may determine the reactor core condition and state of protective barriers;
- identify the challenges to fission product boundaries in different reactor states, including shutdown states;
- evaluate the timing of such challenges to improve the potential for successful human intervention;
- identify the reactor systems and materiel resources that may be used for accident management purposes;
- verify that accident management actions would be effective to counter challenges to protective barriers;
- evaluate performance of equipment and instrumentation under accident conditions;
- develop and validate computational aids for accident management.

3.95a Plant capabilities should be analysed in connection with an in-vessel phase of a severe accident as follows:

- Hydrogen production in the vessel and its release as input information for the design of a hydrogen treatment system;
- In-vessel melt retention both by internal and external vessel cooling;
- Melt composition and configuration, and reactor pressure vessel failure as an input for the core catcher design;
- Reliable depressurization to avoid high pressure vessel failure;
- Long term fission product release from the reactor core;

3.95b For the ex-vessel phase, plant capabilities should be analysed including:

- Reliable depressurization of the containment to avoid high pressure containment failure;
- Hydrogen sources and distribution as input information for the design of a hydrogen treatment system;
- Ex-vessel steam explosion, high pressure melt ejection (HPME) and direct containment heating (DCH) issues;
- Melt composition and configuration as input for ex-vessel melt retention devices;
- Fission product sources and distribution within the containment with special attention to the long term behaviour.

3.96 Best estimate computer codes assumptions and data regarding initial and boundary plant conditions with appropriate consideration of uncertainties in the determination of the timing and severity of the phenomena should be used. [Rephrased]

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

3.98 All phenomena (thermal-hydraulic, structural) important for assessment of challenges to integrity of barriers against releases of radioactive materials as well as for source term assessment should be addressed. Multi-unit accidents should be analysed where sites have more than one unit. [Rephrased]

3.99 A sufficiently broad set of accident scenarios adequately covering potential evolutions of accident conditions and a comprehensive set of plant damage states (PDSs) should be identified. Such scenarios should be grouped into representative PDSs[11]. PSA Level 1 and 2, if available, in combination with engineering judgment should be used for selection of the scenarios [10, 11]. [Rephrased]

3.100 [Merged with 3.1]

3.100a If generic plant analysis is used for development of accident management guidance an assessment of its applicability for the specific plant should be performed. [moved from 3.104]

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

3.102 Sufficient input for development of 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;
- the time windows available for performing the actions;
- the prioritisation and optimisation of strategies;
- the evaluation of capability of systems to perform intended functions;
- the expected trends in the accident progression;
- the conditions for leaving severe accident management domain;
- the computational aids development.

3.103 Sufficient information regarding environmental conditions for assessment of the survivability of the plant equipment including instrumentation needed in accident management, as well as for the assessment of the working conditions/habitability of working places for personnel involved in the execution of the accident management actions should be provided. [Rephrased]

[11] Many categorization schemes are possible. Level 2 PSAs contain such categorization schemes in IAEA Safety Guide Series No. SSG-4 [12]

3.104 [Combine with 3.100a]

3.105 The following aspects of accident scenarios that would lead to core damage and subsequent potential challenge to fission products barriers should be considered; [Rephrased]

- Sequences with inappropriate operator actions (errors of omission or errors of commission) leading to core damage;
- Availability and functionality of equipment including instrumentation, and the habitability of working places under anticipated environmental conditions

3.106 [Combined with 3.96]

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

3.108 All analysis results should be evaluated and interpreted with due consideration given to code limitations and associated uncertainties. [12] The appropriateness of carrying out sensitivity analyses should be evaluated when computer code results are relied upon for making critical decisions. [Rephrased]

3.109 [Delete redundancy phrase]

STAFFING, QUALIFICATION AND WORKING CONDITIONS FOR SEVERE ACCIDENT MANAGEMENT

Staffing and qualification

3.110 A nominative list of persons that will be part of the accident management should be established. This list should account for accidents developing over a long period so that adequate shift manning is maintained.

3.111 Adequate staffing levels and personnel qualifications should be established for implementation of accident management measures taking into account the possibility that all units can be affected concurrently including simultaneous accidents and taking into account the requirements for emergency response. Staffing should be capable of sustaining an adequate response until relief arrives when the plant is isolated for some time.

[12] Code limitations and associated uncertainties for severe accident analysis is refereed in IAEA Safety Report Series SRS No. 56, [25]

Working conditions

3.112 Acceptable habitability should be provided to plant and external support staff in situations where the site is partially or totally isolated from continuous offsite support.

3.113 Shift turnover documents should be prepared. During turnovers the new shifts should be provided the accident-related information as well as other information deemed appropriate to maintain continuity in strategies for managing the accident. [Rephrased]

3.114 Contingency plans should be developed for; [Rephrased]

- situations where accident management staff have been incapacitated;
- situations when accident management staff should be evacuated;
- situations when outside support may be delayed so that main control room staff can continue the accident management actions.

3.115 Contingency plan, training, and guidance should be developed to help staff cope with the emotional stress affecting performance during a natural disaster or nuclear accident.

3.116 A highly reliable communication network between the different locations of the emergency response organization should be used. Guidance should be put in place for measures to be taken if offsite communication fails and only the onsite emergency response organization remains functional. The effects of a station black out and the potential for damage from extreme external hazards on the communication equipment should be considered.

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

Responsibilities and lines of authorization

3.117 The person having authority for deciding implementation of actions and strategies in different phases of an accident should be identified. Decision makers and selected members of the emergency response team coping with the consequences of extreme events should be trained to lead under extreme conditions and demonstrate their leadership abilities during exercises or drills.

3.118 Responsibilities and authorities for implementation of certain accident management actions with a potentially significant impact should be established in the entire emergency response organization. The emergency response organization could include elements as depicted in Figure 2.

3.118a The emergency director / incident commander (or other person with clearly assigned decision- making authority) should have the authority to take any necessary actions to mitigate the event including venting containment or injecting low quality water into the reactor pressure vessel or steam generator without the need for external authorization. If local regulations require external authorization for such actions, steps should be taken to gain concurrence in advance of criteria for which these actions may be carried out. [Separate with 3.118]

3.119 Roles of personnel involved in accident management should be assigned in three categories of functions:

(1) Evaluation/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 these duties are often called ‘evaluators’);

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

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

3.120 Contingency plans should be prepared for the case where a certain authority level is incapacitated. Such contingency plans should identify an alternative authority and decision-maker.

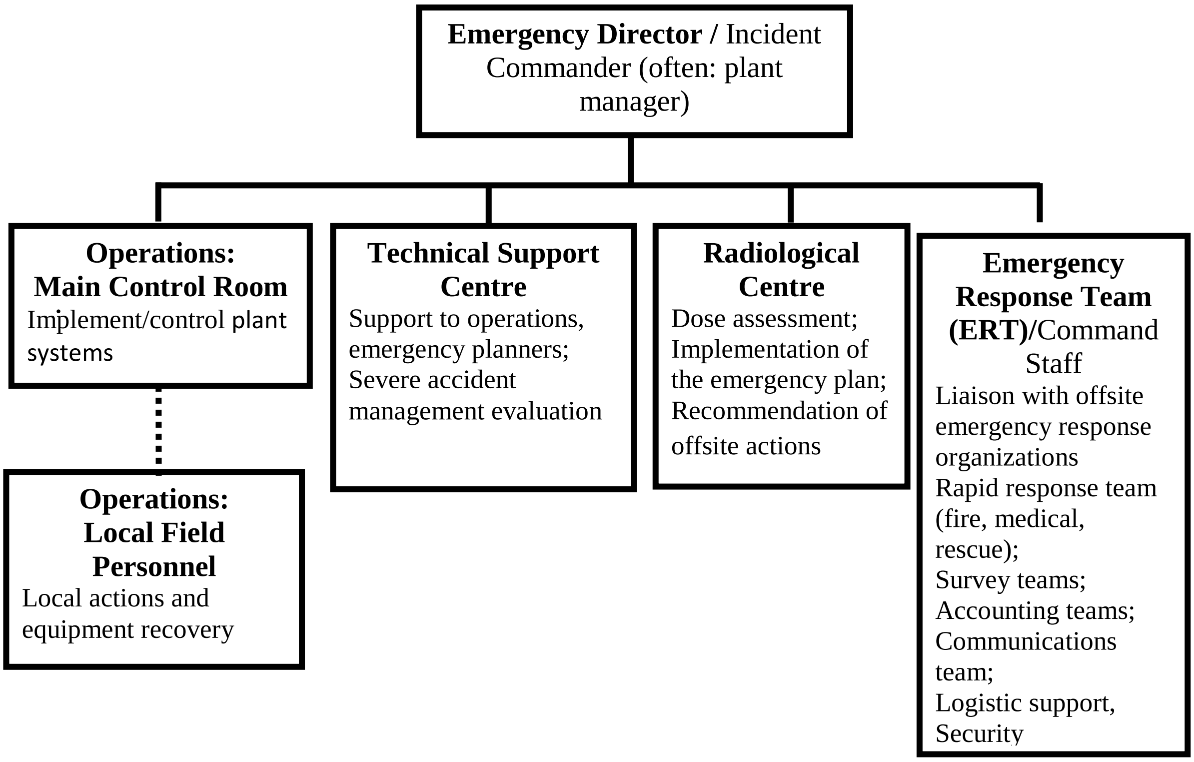

Figure.2 Example layout of the technical elements of the onsite emergency response organization

3.121 When offsite support to accident management is considered responsibilities, priorities and contingencies should be addressed in a way that minimizes the possibility of negative interaction between activities performed by onsite and offsite teams. Accident management should be implemented to ensure that all teams have a common situational awareness.

3.122 [Delete]

3.123 [Delete]

3.124 The decision making authority should lie with a high level manager denoted in this guide as the emergency director. The emergency director should be granted the authority to decide on the implementation of accident management measures proposed by the Technical Support Centre or, when necessary, based on his/her own judgment. The emergency director should maintain a broad understanding of the actual status of the plant, plant capabilities and vulnerabilities and key accident management actions, including their offsite effects.

Transfer of responsibility and authority

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

3.126 Transfer of responsibilities and decision making authority from the main control room staff to an appropriate level of authority 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.

3.127 In transferring the overall authority for accident management from the main control room to the emergency director13, the functions that remain in the main control room and 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. room cooling service water) 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 main control room staff is 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.

3.128 If transfer of authority to offsite persons is considered, it should be verified that such persons have the required background to efficiently exercise such authority. The impact of external hazards should be considered.

3.129 It should be noted that transfer of responsibilities and authorities during an accident in itself poses risks. Hence, such transfer should take place at a point in time that minimizes such risks 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 necessary actions. Hence, formal transfer should not take place until the new decision maker is ready to assume his/her role. Transfer of responsibilities and authorities should be consistent with the emergency plan.

[13] In some Member States (e.g. Russian Federation), transfer of emergency management responsibility to the authorized person occurs when this person arrives to the Emergency Response Organization (ERO) in all cases, irrespective of severity of the accident.

Technical Support Centre

3.130 Criteria for activation of the technical support centre should be unambiguous and clearly specified in plant procedures or onsite emergency plan. Accident management measures should continue to be decided and carried out by the control room staff until the technical support centre is functional with achieving a quorum of staff and acquiring situational awareness. When there are multiple support teams their responsibilities and interfaces should be defined. Additional details are referred in paragraph 4.2.

3.131 Depending on the situation, the technical support centre may be activated in the preventive domain. The technical support centre should provide technical support to the control room staff, and, where applicable, to other parts (including offsite) of the emergency response organization by performing evaluations and recommending mitigatory actions to the decision making authority.

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

3.133 Support from qualified organizations including the plant vendor or designer should be sought, as necessary, for the implementation of additional appropriate accident management recommendations. The mechanisms for calling on early support should be established, and the capabilities of support organization should be verified on a periodic basis.

3.133a If there is to be any involvement of the regulatory body in the decision making it should be defined how this is to be done.[14] [moved from 3.135]

3.134 Rules for information exchange between the various teams of the emergency response organization and outside organizations should be defined. The mechanisms for ensuring the flow of information between the technical support centre and the control room as well as from the technical support centre to other parts of the emergency response organization, including those responsible for the execution of onsite and offsite emergency plans should be specified. Oral communication between the technical support centre and the main control

[14] Some Member States have specific regulations on regulatory body involvement; in other cases involvement of the regulatory body may not be required but may be prudent (e.g. for containment venting).

room staff should be done by a member of the technical support centre who is a licensed operator or similarly qualified person. As the occurrence of a severe accident will generate extensive communication between onsite and offsite teams care should be taken that this communication does not disrupt the management of the accident at the plant.

3.135 [moved 3.13a]

3.136 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 manual transfer of plant data between main control room and technical support centre is needed this should preferably be done by a dedicated member of both main control room and the technical support centre. The plant information in the technical support cintre should be recorded and monitored appropriately.

3.137 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 offsite facilities. [Rephrased]

3.138 The onsite centre (emergency response facility) should provide reasonable assurance of being operable and habitable under a range of postulated hazardous conditions, including extreme external hazard conditions not considered in the design. [Rephrased]

Interfaces with emergency preparedness and response

3.139 Appropriate interfaces between the accident management programme and the emergency response organization should be established for an effective response to emergencies (including nuclear or radiological emergencies, both onsite and offsite).

3.140 Arrangements for local response should be coordinated with the site, corporate, regional, state, and national level concerning functions, responsibilities, authorities, allocation of resources and priorities.

3.141 The site emergency plan should define the overall emergency response organization of a nuclear power plant. The responsibilities defined in the accident management programme should be coordinated with the emergency plan via clearly defined interfaces in order to ensure a consistent and coordinated response to severe accident conditions. A review of the emergency plan and accident management programme should be performed with respect to the actions that should be taken according to the emergency response plan and accident management strategy, to ensure that conflicts do not exist.

3.142 [Delete]

3.143 Use of the SAMGs must interface with the organizational structure and actions defined in the emergency plan to ensure a consistent and coordinated response to severe accident conditions. Therefore, as part of the plant specific SAMG implementation, both the emergency plan and accident management strategy should be reviewed with respect to the SAMG actions and emergency response plan or accident management programme to ensure that conflicts are resolved. This review might recommend changes to the emergency plan to eliminate such conflicts.

For multi-unit sites

3.144 For multi-unit sites, the site emergency plan should include the necessary interfaces between the various parts of the overall emergency response organization. Unit emergency directors may be assigned to decide on the appropriate actions at that unit. 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 the given site, appropriate agreements should be established on coordination of emergency response activities including accident management guidance.

VERIFICATION AND VALIDATION OF SEVERE ACCIDENT MANAGEMENT PROGRAMME

3.145 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 document instructions with referenced equipment, user-aids and supplies (e.g., non-permanent equipment, posted job aids, strategy evaluation materials, etc.) [17]. The validation process should demonstrate that the document provides the instructions necessary to implement the guidance.

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

3.147 All accident management procedures and guidelines should be verified and validated. Changes made to guidelines and procedures should be re-evaluated and re-validated, on a periodic basis, to maintain the adequacy of the accident management programme.

3.148 Possible methods for validation of the procedures and guidelines are an engineering simulator including a full scope simulator (if available) or other plant analyser tool, or a table top method. The most appropriate method or their combination should be selected taking into account the role of each target group in emergencies.

3.149 If using a full scope simulator, the 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 simulate a degraded or unavailable instrumentation response, or a delay in obtaining the information. [Rephrased]

3.150 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 multi-unit sites, to the practicality of using backups that could be provided by other units.

3.151 A cross-functional safety review of the plant should be performed with the objective of fully understanding all accident management implications. This review should incorporate a plant walk-down for assessing which kind of difficulties could exist for practical implementation of accident management measures in case of an internal and/or external hazard.

3.152 All equipment needed in the accident management programme including non-permanent equipment should be tested according to the importance of the equipment to the fundamental safety functions.

3.152a The guidance should be prepared to test the permanent and non-permanent equipment and the assembled sub-system needed to meet the planned performance. The periodicity and type of testing should be conducted in accordance with manufacturer's recommendations. Tests should include needed local actions, contingencies, and its proper connection to plant equipment, access to the site, offsite actions, multi-unit events, emergency lighting, etc., and the time needed for these actions (if appropriate). Guidance should be provided for maintenance and periodic testing to assure proper functioning.

3.153 Staff involved in the validation of the procedures and guidelines should be different from those who developed the procedures and guidelines. Developers/Writers of plant specific procedures and guidelines should prepare appropriate validation scenarios and their participation as observers to the validation process may be beneficial [18].

3.154 The findings and insights from the verification and validation processes should be documented and 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 in order to provide for any future revalidation.

SEVERE ACCIDENT MANAGEMENT TRAINING, EXERCISES AND DRILLS

3.155 Personnel responsible for performing accident management duties should be trained to acquire the required knowledge, skills, and proficiency to execute their roles. A comprehensive training programme for accident management should be prepared. Training should include a combination of techniques such as classroom training, exercises and drills, tabletop exercise[15] and use of simulation tools.

3.156 The decision makers should be trained to understand the consequences and uncertainties inherent in their decisions; the evaluators should ensure that they understand the technical basis upon which they will base their recommendations and the implementers should ensure that they understand the actions that they may be asked to take.

3.157 Training should be developed using a systematic approach to training. This includes identifying training needs, defining the training objectives, identifying 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.

3.158 Training should be established and implemented for each onsite group and offsite group involved in accident management. Training should be commensurate with the tasks

[15] A structured discussion exercise based on a scenario or set of conditions for potential emergency response situations, among decision makers or responders. The objective is both educational and developmental in that disconnects, perceptions, and procedures can be identified easily and then corrected.

and responsibilities of the participants, taking into account the appropriate technical level needed for each group. In-depth training should be considered for people entrusted with critical functions in the accident management program.

3.159 Training material should be developed by subject matter experts and qualified trainers. Experts could assist in:

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

3.160 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 expected to occur during an event. Drills should extend over a time period long enough not to unacceptably distort plant response, and allow testing transmission of information during shift changes. Special drills/exercises should be developed to practice operating shifts and technical support centre staff changeover and information transfer between different teams. The training should include accidents occurring simultaneously on more than one unit, from different reactor operating states and in the spent fuel pool. Training should consider unconventional line-ups of the plant equipment, the use of non-permanent equipment (such as diesels or pumps) as well as repair of the equipment.

3.160a Training material should address implementation of strategies under adverse environmental conditions including those resulting from external hazards under potentially high radiation situations and under the influence of stress on the anticipated human behaviour. [Separate with 3.160]

3.161 Initial training as well as refresher training should be developed for all groups involved in accident management. The frequency of refresher training should be established based on the difficulty and importance of accident management tasks. Replacement staff must be trained appropriately. 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 to communicate with various stakeholders.

3.162 Exercises and drills should be based on scenarios that require application of a substantial portion of the overall accident management programme in concert with emergency response and in 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.

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

3.164 Criteria for evaluating the effectiveness of a drill or an exercise should be established. Such criteria should characterize the ability of the team participating in the drill or exercise to understand and follow the evolution of plant status, to reach sound decisions (including unanticipated events) and initiate well-founded actions, meet job performance criteria and drill objectives [17].

3.165 Some of the scenarios used for exercises and drills should go far into the core damage state and eventually result in failure of the reactor pressure vessel and containment. Attention should be paid to exercises that enhance the awareness of main control room personnel, technical support centre members or engineering staff to the need and possible consequences of defeating or resetting control and logic blocks for implementing some successful strategies.

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

UPDATING SEVERE ACCIDENT MANAGEMENT PROGRAMME

3.167 The need to update the accident management programme should be assessed as new information becomes available which 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.

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

3.169 When modification of the accident management programme is deemed appropriate, the operating organization should be responsible for establishing an action plan aimed at prioritising activities needed for implementation of said modifications. Where a generic accident management programme is used, such processing should involve the vendor of the generic program. The action plan should identify the timeframe and the organization in charge of practical implementation of the modifications.

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

3.171 New insights from international research on accident phenomena and industry operating experience (including lessons learned from events) should be evaluated on a regular basis and a judgment made on their potential impact for accident management programme by the operating organization/utility. Exchange of information with peers should be used to provide continuous improvement of the accident management guidance.

3.172 Any update of the accident management programme should include, as appropriate, revision of background documents including supporting analysis used for their implementation.

MANAGEMENT OF SEVERE ACCIDENT MANAGEMENT PROGRAMME

3.173 Development of an accident management programme should be the responsibility of the operating organization and be consistent with the applicable IAEA safety requirements and guides on this subject presented in Refs. [16, 18, 19], as well as applicable international standards or national requirements.

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

EXECUTION OF SEVERE ACCIDENT MANAGEMENT PROGRAMME

4.1 In case of an emergency, in particular one taking place in combination with an internal or external hazard, plant staff should assess the overall situation onsite and ensure that their emergency command and control structures are capable of directing responses in accordance with established guideline sets. If required, contingencies developed to re-establish the command and control structure should be implemented.

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

4.3 The technical support centre should reassess plant conditions 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 of all recommendations should be kept.

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 it is being directed to take and should report back the progress of the actions taken and the impact that these have on the plant. Oral (telephone or other suitable means) communication to the main control room staff including supplementary control room staff should preferably be carried out by a technical support centre staff member who is a licensed operator. A major step prior to recommending or attempting executing an action is to check feasibility of proposed actions.

4.5 The essential plant parameters should be displayed in an easily accessible way, e.g. by optical means (displays) or by wall boards. Long-term station blackout should 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 planned releases of radioactive material. Adequate technical means should be available for this.

4.6 The timing and magnitude of possible future releases as a consequence of severe accident management guideline actions or their failure, such as deliberate releases, or isolation of release paths, should be estimated at regular intervals, and should be communicated in a suitable form through proper channels to the organization 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 technical support centre should convene in sessions at regular times and should leave sufficient time for individual staff members to do their analysis between these regular sessions.

4.7a The staff responsible for execution of accident management should be adequately qualified and staffed according to the evolving accident conditions. [Moved from 2.13]

4.8 The technical support centre or any equivalent structure(s) should ensure that external organisations are aware of planned actions with potential impact on the plant surroundings. Through consultations it should be ensured that offsite response organizations are aware of and prepared for planned releases. Alternatively, the releases should be delayed to a later time, if such a shift is compatible with the severe accident management actions foreseen. Final decision making rests with the person denoted in this guide as the emergency director.

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

4.10 The process for decision making should take into account the fact that decisions may have to be made in a very short time frame. A basic principle is that the decision making process should be matching with the time frame of the evolution of the accident.

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ANNEX I Examples of SAMG Implementation in Nuclear Power Plants

A1-1 France

In France, SAM guidelines applicable to the Électricité de France S.A. (EDF; Electricity of France) nuclear fleet (d'un Guide d'Intervention en situation d'Accident Grave (GIAG) in French) have been developed under the form of both flowcharts and text. There are two parameters that are used for entry in GIAG, one characterizing very high core exit temperature, the other high containment activity

Either criterion can be used for entering GIAG and subsequent performance of a whole set of immediate actions by main control room personnel.

SAM guidelines (OSSA) have also been developed for the EDF European Pressurized Reactor (EPR). The main parameter used for entry in GIAG is the core exit temperature.

Upon entering GIAG, EOPs are exited. However, some specific actions that are called upon by EOPs and are beneficial for SAM 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 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 for allowing response teams to make an informed decision.

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 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 think appropriate for dealing with the identified development.

GIAG doesn't consider any pre-defined long-term provision nor incorporate exit criteria to long-term measures. Long-term provisions are to be decided by Emergency Response teams. In relation with the LTO of Gen II PWRs, strategies with specific provisions for long term management after a severe accident are being developed by EDF

The importance of getting reliable information on capabilities or performing actions, which are helpful for protecting the third barrier, is recognized. Examples of such information or actions are:

- Use of computational aids available for supporting the diagnosis of plant status and informing the decision making process and the plant evolution prognosis;
- Immediate opening of all safety relief valves (SRVs) (if not opened before)[16] for preventing RPV failure at high pressure and limiting the risk of debris dispersal in the upper parts of the containment (and potential subsequent direct containment heating (DCH) in case of reactor pressure vessel (RPV) failure);
- Limiting the risk of reactor coolant system (RCS) re-pressurization above 20 bars, before vessel failure, through specific RCS water injection limitations;
- Limiting the risk of consequential steam generator tube ruptures (SGTRs) that would lead to containment bypass through immediate actions implemented upon entering GIAG;
    - isolating radioactive SGs;
    - filling non-radioactive SGs with water;
    - depressurizing the RCS, all being;
- Detection of RPV failure using temperature measurement in the reactor pit, with the potential of confirming the information through cross-checking other sources of information;
- Injection of Water in the core with the objective to limit the core degradation or cool the corium
- Activation of the containment spray system to prevent containment over-pressurization and remove thermal energy from the containment atmosphere[17];

[16] Dedicated lines in case of European Pressurized Reactor

[17] This actuation is required by the ERT when deemed appropriate (essentially for preventing unacceptable de-inertization of the containment atmosphere) also leads to the flooding of the reactor pit.

- Use of PARs (Passive Autocatalytic Recombiners) for eliminating Hydrogen from the containment atmosphere; and
- Heating of the pipe situated between the intake of the sand bed filter inside containment and the containment filter for preventing steam condensation in the tube and in the filter[18].

[18] For limiting the risk of Hydrogen combustion in very specific situations

A1-2 Germany

Although emphasis has been put, in Germany, on the prevention of severe accidents, hardware modifications as well as Emergency Operating Procedures (EOPs) have been made or developed after the Chernobyl accident: they include, in particular:

- The installation of filtered containment venting
- The installation of Passive Autocatalytic Recombiners (PARS) on PWR units
- Implementation of Containment Inertization on BWR units

The development of SAMGs has been started in 2010, and full completion was obtained at the end of 2014.

The Severe Accident Management Manual (SAM-M) for PWRs includes:

- The diagnosis of the plant (damage) state,
- Related strategies for mitigating the consequences of a Severe Accident,
- Detail sheets for all measures within the strategies,
- Links to EOPs that are relevant for mitigatory strategies.

SAM-M is managed using clear criteria in the Accident Management Flow Chart (AMFC). There are two entry criteria to SAM for at-power states. For shutdown states, an additional dedicated criterion is used.

Upon entering SAM, 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.

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

To enable prioritizing measures considered for preventing massive core damage and RPV failure, the level of core degradation must be known. Three core degradation states are used for this purpose:

- Core state “A” characterizes a low degradation level (rod-like geometry);
- Core state “B” characterizes ongoing core degradation until RPV failure; and

- Core state “C” means the RPV has failed.

It should be noted that core states A and B are practically indistinguishable by means of measurements. Therefore strategies are implemented to apply for both states (“A/B state”). However, strategies are robust in a sense that no harmful consequences will arise from using A/B-strategies when RPV failure is not detected immediately (core state “C”).

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

- The containment is intact and there is no obvious risk of losing containment integrity;
- Containment integrity 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 containment isolation failed; and
- The containment has been impaired (leak or rupture).

Based on these plant states, dedicated strategies are implemented to prioritize the performance of adequate mitigatory measures. Although parallel execution of several measures is not excluded, performance of previously initiated more efficient measures (measures with a higher level of priority) must not be jeopardized. In addition postponing implementation initiation of measures having a lower level of priority until success of previously implemented ones has been recognized is not recommended.

When a high level action has been started, the Emergency Response Team (ERT) goes to the next high level action considered in the flow chart without the need for evaluating whether previously implemented actions are successful. To recognize any transition between different plant states, the ERT regularly checks the parameters that define the plant damage states for confirming whether implemented actions work satisfactorily or not. When applicable, criteria to terminate certain measures or effectiveness conditions and criteria are given in the detail sheets. In case of change of plant damage state, implementation of the current strategy must be stopped and the execution of the new strategy starts from the top. However, all measures currently in execution will not be terminated until termination is explicitly demanded in the new strategy.

For all candidate high level actions, dedicated information is provided. In particular, the cons of implementing a specific measure are listed to allow the ERT 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 pros exceed cons. If this were not the case, the ERT should not advise implementation of the planned action.

SAM guidelines neither consider implementation of pre-defined long-term provisions nor use any exit criterion for long-term measures.

The importance of getting 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 maintaining the second barrier or the third barrier are:

- Computational aids used for supporting the diagnosis on plant state , the decision making process and the prognosis on plant evolution, including the determination of the required flow for removing decay heat from the core;
- Non-graded 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 RPV failure and subsequent transfer of core debris to the upper parts of the containment with a potential risk of Direct containment Heating, is a considered measure. This however doesn’t prevent temporary re-pressurization of the RCS below 20 bars under some specific plant conditions;
- Prevention of bypass sequences resulting from consequential SGTRs through isolating in advance dry Steam Generators that would likely be impossible to feed during the accident;
- Mitigation of SGTRs through isolating all failed Steam Generators or injecting water in failed non-isolated Steam Generators;
- Monitoring parameters that allow confirming that the RPV has not failed, minimum grace period provided by deterministic analyses before RPV failure and trending parameters that could allow characterization of RPV failure are also used. For cases where the differentiation between different core states cannot be done using existing instrumentation only, it should be possible to use alternate means, such as computational aids; and
- Water injection into the Reactor cavity (via RCS) for preventing or limiting

basemat attack and scrubbing fission products in case of RPV failure;

- Use of a flammability diagram for evaluating the risk of losing containment integrity in case of flammable mixture, and recommending tripping Containment Heat Removal systems when measurements indicate that the concentration of Hydrogen inside the containment is nearing the flammability limit; and
- Inertization of the filtered venting system for preventing possible system degradation

A1-3 USA

The main characteristic of the US plant is that operating plants have been developed by at least four vendors (Westinghouse [WH], Babcock & Wilcox [B&W], Combustion Engineering [CE] and General Electric [GE]). The first three vendors are PWR vendors, while GE is the sole vendor of the BWR technology in the US. This has led to the development of four different approaches to the severe accident management guidelines (SAMGs), and, though all PWR operators are now members of a unique Owners Group, (Pressurized Water Reactors Owners Group [PWROG]), there is no unique approach for PWRs at this time. However, the PWROG 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 PWR approach will be modelled after the Westinghouse (WH) version of the SAMGs.

Considering entrance in SAMGs, once done, WH SAM relies on two logic diagrams, one related to immediate severe challenges to the integrity of fission product barriers and ongoing releases, a second one for following a certain chronology of anticipated challenges to fission product barriers. The other two PWR vendors rely on logic diagrams to establish the Electric Power Research Institute (EPRI) Technical Basis Report (TBR) plant damage states.

Once entering the SAMGs domain, all EOPs are exited, except in the CEOG, where EOPs and SAMGs are executed in parallel. However, in the approach retained by the WOG or the BWROG, some important actions required in EOPs can be repeated, but SAMGs have priority upon EOPs. In the B&WOG approach, no re-entrance in EOPs is considered. All Owners Groups address the pros and cons of expected actions, with a level of detail adapted to their needs. The WOG has adopted tables with the pros and cons of each expected action, and possible ways for mitigating the consequences of cons, while the CEOG and the B&WOG have opted for putting cautions in each guide.

For PWRs, priorities for implementing strategies or actions are given in a logic diagram, an answer to a question in a logic diagram being always linked to an earlier question, but implementation of an action doesn’t require full completion of previously implemented actions. For BWRs, all guidelines related to core and containment behaviour are executed in parallel. When an action fails, WOG guidelines only provide alternatives.

There are no predefined long-term provisions. As for exit condition, WOG has some based on core exit temperature, primary pressure, containment pressure, hydrogen concentration and releases.

The importance of getting 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 for protecting the second barrier or the third barrier are:

- All PWRs use computational aids, while the BWROG treats this in its Technical Support Guidelines;
- Graded depressurization is not considered, except in the latest version of the BWROG guidelines, that mention slow depressurization for allowing an injection system using a steam turbine (Reactor Core Isolation Cooling System [RCIC]) to run as long as possible through using reactor steam;
- Injection of water in the Steam Generators (number one priority for WOG) or the core (other PWRs or BWROG);
- Injection of water in the Reactor Cavity (common to PWRs and BWR;
- Monitoring parameters that allow confirming that the RPV has not failed for CEOG and B&WOG, that use logic diagram to characterize vessel failure (WOG has no such diagrams); and
- Use of a flammability diagram for evaluating the risk of losing containment integrity in case of flammable mixture (all PWR technology Owners Groups) with various degrees of sophistication,. The BWROG, on the contrary, addresses the issue in their Technical Support Guidelines. Hydrogen risk in venting system filters is not addressed as filtering is not considered in these systems.

A1-4 Japan

Japan Nuclear Regulation Authority (NRA) requires licensees to take severe accident (beyond design basis accidents; B-DBA) management measures and to design SSCs for preventing and mitigating severe accident, taking into account lessons learnt from the Tepco Fukushima-Daiichi NPPs accidents.

The following chapter 1 through 3 describes the outline of new regulatory requirements for light water nuclear power plants against severe accident (SA) measures.

1 Severe Accidents Measures Requirements (Major systems for each measure)

(1) Common Basic Requirements on the SA measures Equipment;

Capacity	• SA Measures Equipment shall be designed to have sufficient capacity required to settle the postulated B-DBA. • Mobile SA Measures Equipment shall be designed to have the required capacity with suitable margins in accordance with the equipment reliability to settle postulated B-DBA.
Environmental and load conditions	• SA Measures Equipment shall be designed to function as required with sufficient reliability under environmental and load conditions during postulated B-DBA.
Operability	• SA Measures Equipment shall be designed to be sure to operate under the conditions during postulated B-DBA.
Diversity	• Permanent SA Prevention Measures Equipment shall be so designed that diversity is considered as much as possible for the Design Basis Accident Measures Equipment to be substituted. • Mobile SA Prevention Measures Equipment shall be as diverse as possible for equipment for Design Basis Accident Measures and permanent SA Prevention Measures to be substituted.
Detrimental impact prevention	• SA Measures Equipment shall be installed so as not to cause any detrimental impact on other equipment.
Easy Changeover	• Equipment and procedures shall be prepared so as to allow easy and certain changeover from normal line configurations in the event that other equipment is used for SA Measures Equipment different from its original use.
Reliable connections	• Measures shall be taken to standardize connecting methods to ensure that mobile SA Measures Equipment and permanent equipment can be easily and surely connected and that such equipment can be used interchangeably between systems and units. Furthermore, multiple connections shall be prepared with appropriate spatial dispersion to avoid disconnection due to common modes.
Seismic and Tsunami Resistance etc. (connecting piping included)	• Appropriate measures (including piping, valves and electrical cables etc. within the building beyond the connections to the mobile SA Mitigation Measures Equipment) for SA Mitigation Measures Equipment Procedures shall be taken so as not to damage the necessary functions for standard ground motion and standard tsunami etc. • SA Prevention Measures Equipment (including piping, valves and electrical cables etc. within the building beyond the connections to the mobile SA Prevention Measures Equipment) shall have the equivalent seismic and tsunami resistance to the Design Basis Accident Measures Equipment to be substituted.

Storage places	• Mobile SA Measures Equipment shall be stored dispersed in different locations, which are not easily impacted by external events (earthquakes, tsunami, etc.). Mobile SA Measures Equipment shall be stored in different locations from permanent SA Measures Equipment.
On-site working conditions	• The locations where SA Measures Equipment are installed shall be selected in such a way that the installation, connection, operation and recovery work of mobile SA Measures can be done even in case of postulated B-DBA, by selecting the suitable place not to be affected severely by the accident or by reinforcing the shielding performance etc.
Securing access routes	• Access routes shall be designed and managed effectively so as to ensure the availability of required access routes outside of buildings needed to transport mobile SA Measures Equipment or to confirm the damage of equipment under the postulated environment.
Prohibition of shared use	• In principle, permanent SA Measures Equipment shall not be shared by more than two nuclear reactors. However this rule shall not apply if risk 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 system: Appropriate organizational system shall be established by the formulation of the procedures and implementation of drills in advance in order to manage B-DBA rapidly and flexibly.

(3) Prepare equipment and procedures for the following measures;

- Measures for reactor shutdown
- Measures for cooling reactor at high pressure
- Measures for depressurizing reactor coolant pressure boundaries
- Measures for cooling reactor at low pressure
- Measures for securing ultimate heat sink for the SA Measures in case of accident
- Measures for cooling, depressurization and radioactive material reduction in the atmosphere of the containment vessel
- Measures for preventing the containment vessel failure due to overpressurization
- Measures for cooling molten core fallen to the bottom of the containment vessel
- Measures against hydrogen explosions inside the containment vessel
- Measures against hydrogen explosions inside the reactor building, etc.
- 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
- Control room
- Emergency response center
- Instrumentation devices
- Radiation monitoring facilities
- Communications devices
- Measures for suppression of off-site radioactive material release

2 Accident Management for External Events beyond Design Basis

(1) Accident management with mobile equipment, etc.

Procedures shall be prepared for the following items under the situation that the plant has suffered large-scale damage due to a large-scale natural disaster or acts of terrorism such as intentional airplane crash. Furthermore, organizational systems and 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 containment vessel failure.
- 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) Specialized Safety Facility

“Specialized Safety Facility” refers to facilities with function to suppress a large amount of radioactive material release caused by containment vessel failure in the event of severe core damage or almost damaged core as a result of acts of terrorism, etc., such as intentional airplane crash, etc.

Specialized Safety Facility shall be installed in accordance with the followings;

- Specialized Safety Facility shall be equipped with adequate measures for preventing the loss of necessary function due to the intentional crashing of a large airplane into the reactor building.
- Specialized Safety Facility shall be equipped with adequate measures for preventing the loss of necessary function due to design basis seismic motion and tsunamis.
- Specialized Safety Facility shall be installed with equipment required to prevent containment vessel failure.
- Equipment shall be designed so as to allow the use over a certain period of time.
- Organization to maintain the function of Specialized Safety Facility shall be established.

3 Evaluation of the Effectiveness of SAs Measures

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

- Licensees must postulate B-DBA which may cause severe core damage and prepare appropriate measures to prevent severe core damage.
- Licensees must postulate the containment vessel failure mode that may occur in conjunction with severe core damage and prepare appropriate measures to prevent containment vessel failure.

(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