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Severe Accident Management Programmes for Nuclear Power Plants

DRAFT SPECIFIC SAFETY GUIDE XXX (DS483)

IAEA
INTERNATIONAL ATOMIC ENERGY AGENCY

FOREWORD
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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.

Contents

1. INTRODUCTION

BACKGROUND

1.1 Design basis accidents are defined as accident conditions against which a facility is designed according to established design criteria, and for which the damage to the fuel, and the release of radioactive material, are kept within acceptable limits [1, 5].

1.2 Design extension conditions comprise accident conditions more severe than a design basis accident. Design extension conditions may or may not involve nuclear fuel degradation either in the core or at other locations where fuel is stored; conditions involving nuclear fuel degradation are termed severe accidents [5].

1.3 Consideration of design extension conditions in the design of new nuclear power plants[1] or in the enhancement of the design of existing nuclear power plants is an essential component of the defence-in-depth approach used in nuclear safety [2-5]. The probability of occurrence of a design extension condition is very low, but it may lead to significant consequences resulting from degradation of the nuclear fuel.

1.4 The design extension conditions should be used to identify the additional accident scenarios to be addressed in the planning of practicable provisions for the prevention of such accidents or the mitigation of their consequences if they do occur - named severe accident management (the term "accident management " includes the management of a severe accident) [5].

1.5 Accident management is the taking of a set of actions during the evolution of accident conditions with the objective of: preventing progression into a severe accident, mitigating the consequences of a severe accident, and achieving a long-term safe stable state [6].

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

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

[1] 'Plant' includes multi-unit sites.

(2) When plant conditions indicate that fuel damage has occurred or is imminent (mitigatory domain of accident management), priority is given to mitigating the consequences of severe accidents through:[2]

- preventing the uncontrolled loss of containment integrity;
- performing any other actions having the potential for limiting fission product releases to the environment and avoiding releases of radionuclides causing long-term off-site contamination.

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

1.7 Effective implementation of accident management is done in existing plants through a severe accident management programme (hereinafter referred to as "accident management programmes") while already the design of new nuclear power plants explicitly includes the consideration of severe accident scenarios and strategies for their management. 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 on-site actions to prevent or mitigate the consequences of a severe accident. 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.

1.8 The accident management programme needs to consider all modes of operation, all possible conditions, including combinations of events that could cause failure of fuel cooling and ultimately significant radiological releases to the environment. An accident management programme requires that plants establish the necessary infrastructure to effectively prevent or mitigate severe accident conditions, mitigate fuel damage, and stabilize the units if fuel damage does occur. This infrastructure should include equipment and supporting procedures necessary to respond to events that may affect multiple units on the same site and last for extended periods, and personnel having adequate skills for using such equipment and implementing supporting procedures.

[2] The second aspect of accident management (to mitigate the consequences of a severe accident) is also termed severe accident management. Accident management is essential to ensure effective defence in depth at the fourth level [2,3]. The aim of the fourth level of defence-in-depth is to ensure that radioactive releases are kept as low as practicable. The protection of the containment function is most important for achieving this aim. Limiting external releases has the potential for minimizing detrimental consequences on the public, the environment and society beyond the site boundary.

OBJECTIVE

1.9 This Safety Guide presents recommendations for the development and implementation of an accident management programme for meeting the requirements for accident management that are established in relevant IAEA Safety Requirements for design in Sections 2 and Section 5 of Ref [5], commissioning and operation in Sections 3 and 5 of Ref. [6], safety assessment in Section 4 in Ref. [7] and emergency preparedness and response in Sections 2 and 3 of Ref. [8]. It is also applicable for further enhancements of nuclear safety by means of reasonably practicable safety improvements.

SCOPE

1.10 This Safety Guide provides recommendations for the development and implementation of an accident management programme during all modes of operation for the reactor, the spent fuel pool and or any other location of fuel to prevent and/or to mitigate the consequences of severe accidents.[3]

1.11 Although the recommendations of this Safety Guide have been developed primarily for use for both existing and new water cooled reactors, they are anticipated to be valid to some extent for other types of nuclear 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 as a reference document for preparation of their relevant safety requirements.

STRUCTURE

1.13 This Safety Guide consists of three main sections and three annexes. 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 an accident management programme are provided in Section 3. Recommendations for the use of accident management procedures and guidelines are described in Section 4. Annexes I, II and III provide descriptions of specific severe accident management guideline (SAMG) implementation approaches in different countries (France, Germany and the United States of America).

[3] More details can be found in Reference [8].

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

Subject/Attribute	Preventive domain	Mitigatory domain
Aim	Prevention of fuel damage, through fulfilment of a set of safety functions of primary importance (‘critical 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
Establishment of priorities	Establishment of priorities among the various ‘critical 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)	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 control room, or decision making for complex tasks, if deemed appropriate	Technical Support Centre (or emergency response facility) responsible for evaluation/recommendation of actions
Procedures/ guidelines	Use of procedures for preventive accident management measures (emergency operating procedures [EOPs]) by the control room[4]	Use of guidance documents (SAMGs) by Technical Support Centre or other designated staff
Use of equipment	Use of all systems still available, use of design margins admissible; possible use of design extension margins upon advice, or decision, by the Technical Support Centre Measures beyond the defined operational range of the systems require advice, or instructions, by the Technical Support	Use of all systems still available, also beyond their design limits, with preference given to safety features for design extension conditions, if available

[4] Either event based or symptom based procedures should be developed for abnormal conditions and design basis accidents. Emergency operating procedures or guidance for managing severe accidents (beyond the design basis) should be developed (see Ref. [14]).

	Centre	
Verification of effectiveness	The effectiveness of the accident management measures can be verified with reasonable accuracy	The effectiveness of the accident management measures can be verified in a limited way Positive and negative consequences of proposed actions to be considered in advance and monitored throughout and after implementation of measures

2. GENERAL GUIDANCE FOR THE ACCIDENT MANAGEMENT PROGRAMME

REQUIREMENTS

2.1 Requirement 20 in Reference [5] establishes the following requirements on design extension conditions for which accident management programmes are to be developed:

> "A set of design extension conditions shall be derived on the basis of engineering judgement, deterministic assessments and probabilistic assessments for the purpose of further improving the safety of the nuclear power plant by enhancing the plant's capabilities to withstand, without unacceptable radiological consequences, accidents that are either more severe than design basis accidents or that involve additional failures. These design extension conditions shall be used to identify the additional accident scenarios to be addressed in the design and to plan practicable provisions for the prevention of such accidents or mitigation of their consequences if they do occur".

2.2 Paragraph 2.10 in Reference [5] establishes the following requirements for accident management in the design of nuclear power plants which is applicable for the development of accident management programmes in general:

> "Measures are required to be taken to ensure that the radiological consequences of an accident would be mitigated. Such measures include the provision of safety features and safety systems, the establishment of accident management procedures by the operating organisation and, possibly, the establishment of off-site intervention measures by the appropriate authorities, supported as necessary by the operating organisation, to mitigate exposures if an accident has occurred".

2.3 Requirement 19 on accident management in the operation of nuclear power plants in Reference [6] establishes:

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

2.4 Paragraph 5.6 in Reference [7] requires that the results of the safety assessment shall be used as an input for on-site and off-site emergency response and accident management.

2.5 Paragraph 5.2 in Reference [8] dealing with minimization of consequences of any nuclear or radiological emergency on peoples' health, property and the environment requires that the transition from normal operation to operations under emergency conditions on the site shall be specified and shall be effectively made without jeopardizing safety. The responsibilities of emergency staff who would be on the site in an emergency shall be designated as part of the transition. It is also required to ensure that the transition to emergency response and the performance of initial response actions do not impair the ability of the operational staff (such as the control room staff) to follow the procedures necessary for safe operations and for taking accident management actions. Hence the need to properly integrate accident management procedures/guidelines and emergency preparedness and response (EPR) should be considered at the development stage.

2.6 Requirement 46 in Reference [9] requires that accident management as part of overall emergency preparedness and response should address the transition from existing exposure situations to emergency exposure situations[5], which arises as a result of an accident or any other unexpected event, in order to avoid or to reduce adverse consequences.

CONCEPT OF ACCIDENT MANAGEMENT PROGRAMME

2.7 An accident management programme should be developed and implemented for all plants including new plants equipped with dedicated systems for prevention and mitigation of severe accidents, irrespective of the core damage frequency and fission product release frequency.[6]

2.8 The accident management programme should address all modes of operation and external hazards[7] relevant for the site considered, taking into account possible dependencies between events.[8] It should also consider external hazards that could result in significant damage to the infrastructure on-site or off-site.

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

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[5] Defined as situations that may occur during the operation of a planned situation, or from a malicious act, or from any other unexpected situation, and require urgent action in order to avoid or reduce undesirable consequences For the purpose of protection, the International Commission on Radiological Protection recommended reference levels for emergency exposure situations should be set in the band of 20–100 mSv effective dose (acute or per year).

[6] The possibility of certain conditions occurring is considered to have been practically eliminated if it is physically impossible for the conditions to occur or if the conditions can be considered with a high level of confidence to be extremely unlikely to arise.

[7] Such as earthquakes, floods, fire, extreme meteorological conditions including extreme weather conditions, or man-made hazards (such as explosives, fires, etc) that could result in significant damage to the infrastructure on-site or off-site.

[8] For example, a seismic event could result in a dam failure upstream of a river site, or in a tsunami for some sea sites

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.

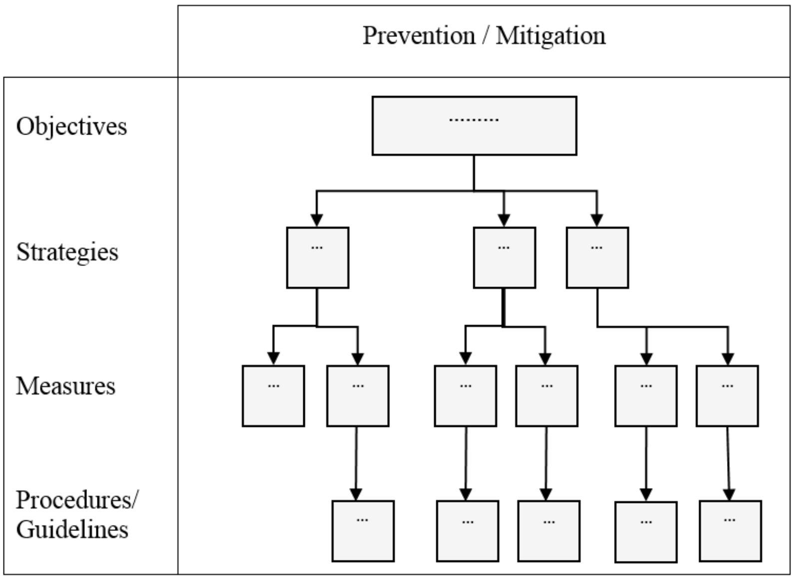

Figure 1 Top down approach to accident management[9]

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

- Preventing or delaying the occurrence of severe fuel damage;
- Terminating the progress of fuel damage once it has started;
- Maintaining the integrity of reactor 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 of fuel;
- Achieving a long term safe stable state.

2.12 From the strategies, suitable and effective measures for accident management should be derived, corresponding to available plant hardware provisions. Such measures may include plant modifications, where these are deemed important for managing accident conditions including severe accidents. Personnel actions initiated either in the control room or local

[9] Strategies are global orientations contemplated for reaching objectives. For example, a strategy for preventing containment by-pass and thereby maintaining containment/confinementintegrity in PWRs is to fill the Steam Generators with water for preventing Steam Generator Tube Ruptures resulting from tube thermal creep. Measures are more detailed recommendations indicating how SGs could be filled (e.g. through using the normal feedwater system, the emergency feedwater system, the plant fire-fighting system, or any other means that could exist after re-alignment of other water systems). Procedures and guidelines are documents provided for practical implementation of measures: they could include methods or information helpful for making decisions and should provide recommendations for practical implementation of such decisions.

actions could be an important part of these measures. During an accident such measures would include use of systems and equipment still available, recovery of failed equipment and use of non-permanent equipment[10], stored on-site or off-site.

2.13 The teams responsible for execution of accident management strategies should be adequately staffed and qualified.

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 working conditions that may exist during accidents including those resulting from external hazards which are more severe than design basis external events.

2.16 When developing guidance on accident management, consideration should be given to the full capabilities of the plant, using safety and non-safety systems and non-permanent equipment, if appropriate. Care should be taken if the possible use of some systems beyond their originally intended function and anticipated operating conditions and possibly outside their design basis is foreseen in the guidance on accident management. 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 waste management or remediation of contaminated areas during accidents should be considered in an appropriate manner. Waste should be processed in such a way that provisions are made to mitigate the consequences if accidents occur [11].[11]

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 during all phases of accident management [12].

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[10] Non-permanent equipment is portable and mobile equipment that is not permanently connected to a plant and is stored in an on-site or an off-site facility.

[11] Relevant information is presented in Ref, [21].

MAIN PRINCIPLES

2.19 Accident management guidance, which includes guidance for management of severe accidents, should be developed for all physically identifiable challenge mechanisms to minimize the impact on public health and safety. Accident management guidance should be developed irrespective of the probability of occurrence of the challenges.

2.20 Accident management guidance should also consider that in case of external hazards, there may be extensive infrastructure damage, so that offsite resources are not readily available, including human resources and/or communication, electrical power, compressed air, water and fuel.

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 dry storage if appropriate, should also be considered in the accident management guidance. For example, management of fuel damage in the spent fuel pool could be dealt with by adding water to the pool in order to restore water level. As large scale maintenance is frequently carried out during planned shutdown states, a high priority of accident management guidance should be the safety of the workforce.

2.22 Accident management guidance should be an integral part of the overall emergency arrangements defined in the plant's Emergency Plan[12]. 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.

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 on-site emergency response organization involved in accident management have been clearly defined, allocated and coordinated.

2.24 Adequate staffing and habitability should be ensured for managing accidents, including those resulting from external hazards. Accident management should consider that some rare events may result in similar challenges to all units on the site. Therefore plans for defining staffing needs should take into account situations where several units on the same

[12] Emergency plan: A description of the objectives, policy and concept of operations for the response to an emergency and of the structure, authorities and responsibilities for a systematic, coordinated and effective response. The emergency plan serves as the basis for the development of other plans, procedures and checklists.

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 Plant conditions at which the transition is to be made from the preventive to the mitigatory domain should be specified and should be based on defined and documented criteria.

2.26 The accident management programme should be reviewed, periodically and in response to major lessons learned, to reflect changes in plant configuration, new results from relevant research, and operating experience. Revisions should be made to the accident management programme where appropriate.

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[13] and should consider the loss or unreliability of indication of key plant parameters.

2.28 Preferably, 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 based on 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[14].

EQUIPMENT UPGRADES

2.30 Items important to safety for the prevention or mitigation of severe 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

[13] This is often called a ‘symptom-based approach containing actions which are taken depending on the values of directly measurable plant parameters. A symptom is a measurable plant parameter that is available to the operator in the control room’. The simple calculations are often called computational aids.

[14] For example, venting the containment, when physically possible, might be initiated at moderate containment pressure to accomodate pressure increases resulting from the generation of non-condensibles or from combustible gas burns or recombination to give further confidence that containment structural integrity will be maintained.

beneficial for improving the accident management programme in providing an efficient mean of reducing risks of an accident in an appreciable way or to an acceptable level.[15]

2.31 When adding or upgrading equipment or instrumentation is contemplated, related design requirements should be such that there is reasonable assurance[16] that this equipment or instrumentation will operate as intended under the anticipated environmental conditions present when it should be used and is either demonstrated by equipment qualification or by assessment of the survivability[17]. The equipment should be designed against accident conditions/loads for severe accidents and external hazards, commensurate with the function that is to be fulfilled and provide adequate margin to failure when it is expected to operate. The equipment should be independent, as far as practicable, from other existing systems during accident conditions.

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.

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

2.34 New equipment, either permanent, or non-permanent that is stored onsite or offsite, should be protected from external hazards that cause the challenge.[18] 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 in the time frame needed should be verified. Impact of the new or modified equipment on the staffing needs as well as expectations for maintenance and testing should be addressed.

FORMS OF ACCIDENT MANAGEMENT GUIDANCE

Preventive domain

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[15] Equipment may not be necessary, in the strict sense of the word, but can be very useful for implementing the accident management programme. For example, passive autocatalytic recombiners remove uncertainties on hydrogen burns.

[16] Reasonable assurance can be obtained through evaluting whether, based on available information coming from different sources there exist a quantifiable positive margin to equipment failure.

[17] Environmental conditions include pressure, temperature, radiative ambiance as well as damage to surrounding structures or buildings

[18] Examples of justification and use of portable (non-permanent) equipment can be found in United States of America developed extensive damage mitigation guidelines (EDMGs) which were developed the reflect to B.5.b requirements and the Flexible Coping Strategies (FLEX) which were a strategy developed following the Fukushima Daiichi accident.

2.35 In the preventive domain, the guidance should consist of descriptive steps, as the plant status is known from the available instrumentation and the consequences of actions can be predetermined by appropriate analysis. The guidance for the preventive domain, therefore, 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, but are typically limited to actions taken prior to fuel damage. Further details on EOPs may be found in Refs [13, 14].

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 not be prescriptive in nature but rather 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 contain sufficient information for the plant staff to reach an adequate 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, procedures, 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 Severe accident management guidelines 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 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 Guidelines or procedures should be developed for all groups participating in accident management such as control room operators, technical support groups, and decision makers in accordance with their respective roles.

Both preventive and mitigatory domains

2.42 For situations that result in normal accident management capabilities being unavailable, such as loss of the command and control structure, support procedures may be developed to provide guidance on using instrumentation and equipment to cope with these conditions[19]. The severe accident guidance should include conditions for use of these support procedures.

2.43 The procedures and guidelines developed for accident management should be supported by appropriate background documentation[20]. This documentation should describe and explain the rationale of the various parts of the guidelines, and should include an explanation of each individual step in the guidance, if considered necessary. The background documentation does not replace the guidelines themselves. It should be available to all staff involved in evaluation and decision making.

2.44 If procedures, guidelines and supporting background documentation are stored in electronic form, hardcopy backups should be available in all evaluation and decision making locations, such as the main control room, supplementary control room and technical support centre[21], so that they can be used as necessary, in particular in case of station blackout .

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 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 a person having a broader perspective of accident management activities and understanding comprehensive implications of the decisions. Major decisions which could have significant adverse effects on

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[19] For example, use of portable (non-permanent) equipment as described in Nuclear Energy Institute's (NEI) 12-06,"Diverse and Flexible Coping Strategies (FLEX) Implementation Guide"

[20] This documentation is sometimes refered to as the Technical Basis Document

[21] Hardcopies should also be made available in all locations used as backups in case of accidents caused by extreme external event.

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[22] should be compatible with the assignment of responsibilities and should be consistent with the other functions considered in the overall emergency response arrangements.[23]

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 negative 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 emergency response organization; the training should be commensurate with their responsibilities in the preventive and mitigatory domains as well as deciding when to transition between domains.

[22] For example, if it has been decided to separate decision making from evaluation, guidance should be available for both functions.
[23] On-site and off-site if appropriate

3. DEVELOPMENT AND IMPLEMENTATION OF AN ACCIDENT MANAGEMENT PROGRAMME

GENERAL REMARKS

3.1 Five main steps should be executed to set up an accident management programme:

(1) Mechanisms that can challenge critical safety functions or boundaries to fission product release should be identified;

(2) Plant vulnerabilities should be identified, considering the challenging mechanisms;

(3) Plant capabilities under challenges to critical safety functions and fission product barriers should be identified, including capabilities to mitigate such challenges, both in terms of available equipment and personnel;

(4) Suitable accident management strategies and measures should be developed, including the use of permanent (fixed) and onsite and offsite non-permanent (portable and mobile) equipment and instrumentation to cope with the vulnerabilities identified; and

(5) Procedures and guidelines to execute the strategies and measures should be developed.

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

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

(2) Identification of important event sequences that may lead to severe accidents using a combination of probabilistic methods, deterministic methods and sound engineering judgement;

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

(4) 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;

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

- some systems beyond their originally intended function and anticipated operational states;
- use of additional non-permanent systems/components, to return the plant to a controlled 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;

(6) 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 The preventive accident management should address the full spectrum of events, including relevant external hazards. All events should be considered on the basis of credibility of occurrence, and possible complications during their evolution that could be caused by additional hardware failures and human errors.

3.4 Selection of events should be sufficiently comprehensive to provide a basis for guidance for the plant personnel in any identified situation. Useful guidance can be obtained from the probabilistic safety assessment (PSA) level 1, from expert judgment or similar studies from other plants, and operating experience from the affected plant and other plants.

3.5 Actions used in preventive accident management should be included in EOPs, and, in case of external hazards, further detailed by special procedures designed for this purpose[24].

3.6 Accident Management guidance should address the full spectrum of challenges to fission product barriers, including those arising from multiple hardware failures, human errors and external hazards,[25] and possible consequential failures and physical phenomena that may occur during the evolution of a severe accident[26]. In this process, even highly improbable failures should be considered.

3.7 For determination of the full spectrum of challenge mechanisms, useful guidance can be obtained from the PSA Level 2, or similar studies from other plants, expert judgment and insights from research on severe accidents. However, identification of potential challenge mechanisms should be comprehensive to provide a basis for guidance for the plant personnel

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[24] For example, Extensive Damage Mitigation Guidelines (EDMGs) in the United States of America.

[25] More details can be found in Ref [20].

[26] For example,steam explosions, direct containment heating, hydrogen burns and containment bypass such as steam generator tube rupture.

in any situation, even 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.

3.8 External hazards with adequate consideration of dependencies should be part of the full spectrum of challenges to safety functions and fission product barriers.

3.9 The development of an accident management programme should consider the following:

- Available or necessary hardware provisions for execution of accident management strategies;
- The possibility and consequences of using erroneous information;
- 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;
- 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;
- Consideration of human factor aspects;
- Integration of the accident management programme within the emergency arrangements for the plant;
- Verification and validation of procedures and guidelines;
- Education and training, drills and exercises and evaluation of personnel skills;
- Supporting analysis for the development of the accident management programme;
- Possible restrictions on the accessibility of certain areas for performing local actions;
- 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.

3.10 Accident management programmes may be developed first on a generic basis, by a plant vendor or other organization, and may then be used by a plant utility for development of a plant specific accident management programme. When adapting a generic 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. On the other hand, any deviations from plant operating requirements and generic accident management guidance 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 accident management programme, a development team of experts with sufficient scope and level of expertise should be assembled, with full support from the upper management of the operating organization.

3.12 The development team should contain staff responsible for the development and implementation of the accident management programme in the plant, including personnel from the training department, operations staff, maintenance staff, radiation protection staff, instrumentation and controls staff, engineering staff, persons responsible for EPR planning and external experts as appropriate.[27] If use of a generic programme has been selected, experts familiar with this programme may support the development team.

3.13 The staff who will be working in the control room or technical support centre or any other organizational unit responsible for evaluation, decision-making, and implementation in the course of an accident should be involved at an early stage of development of an accident management programme, as this provides valuable training for future tasks and feedback.

3.14 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.

3.15 Accident management programmes should assess whether all important challenges to fission product boundaries have been addressed, including those resulting from external hazards.

3.16 Accident management programme controls should be established to ensure that accident management guidelines are not adversely impacted following plant changes, including plant modifications, procedure and training programme changes.

IDENTIFICATION OF PLANT VULNERABILITIES

3.17 A safety assessment should be performed to identify and consider all credible challenges resulting from individual events or combinations of events that could cause failure of barriers against release of fission products. For external events, the safety assessment

[27] Examples of the composition of a core development team are presented in Ref. [15].

should consider identified margins to events in which the consequences can significantly worsen for small changes in the event magnitude.[28]

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

3.19 The vulnerabilities of the plant to challenging conditions should be identified. It should be investigated how specific accidents will challenge critical safety functions, and, if these are lost and not restored in due time, how the integrity of fission product barriers including fuel will be challenged. The possibility of being left with non-permanent (portable and mobile) equipment only for mitigating some challenges should be contemplated. Vulnerabilities resulting from the failure of command and control due to loss of control room or impairment of the capability to set up the on-site Emergency Response Organization should also be addressed.[29]

3.20 The vulnerabilities to external hazards that can impact the use of accident management features, both permanently installed as well as non-permanent, should be identified. It should be investigated how specific external hazards can interfere with the use of accident management features.[30]

3.21 The behaviour of the plant during severe accidents, including those caused by external hazards, should be well understood with identification of the phenomena that may occur together with their expected timing. The severity of these phenomena should be assessed. In the severe accident domain, analysis results should be collected and set out in a report that could serve as the technical basis[31] for severe accident management.

3.22 The information regarding the plant behaviour in accident conditions should be obtained using appropriate analysis. Other inputs should also be used, such as the results of research on severe accidents, operational experience including insights from other plants and

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[28] Also called "cliff-edge effect". According to the IAEA Glossary: "In a nuclear power plant, an instance of severely abnormal plant behaviour caused by an abrupt transition from one plant status to another following a small *deviation* in a plant parameter, and thus a sudden large variation in plant conditions in response to a small variation in an input.

[29] Vulnerabilities could be created by loss of communication with the control room, physical damage to the control room (e.g. fire) harsh environmental conditions in the control room (radiological conditions, toxic gases, smoke, …) or staff injuries or even death.

[30] The investigation should be done especially for such cases where extreme external events could lead to design extension conditions which require the use of accident management measures.

[31] An example of a generic technical basis is provided in Electric Power Research Institute (EPRI) report on *Severe Accident Management Guidance Technical Basis Report*, Volumes 1 and 2, TR-101869-V1 and TR-101869-V2, EPRI, Palo Alto, CA (1992).

engineering judgment. Consideration should be given to uncertainties in the severe accident knowledge base and the assumptions made in models and analysis.

Multi-unit sites

3.23 Effectiveness of equipment and response centres (e.g. control room and/or technical support centre) that are shared by different units should be assessed for cases where accidents occur simultaneously on several units. Based on the result of such assessment, potential alternate solutions could be defined and evaluated and appropriateness of implementation made accordingly.

3.24 If structures, systems, and components (SSCs) whose use is contemplated for severe accident management are shared between two or more units, an assessment should be performed whether safe shutdown is achievable on the other unit(s) should an event requiring such shutdown occurs. Decisions should be made on the basis of such assessment.

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 safety systems, as well as use of non-dedicated systems, unconventional line-ups and hook-up connections for non-permanent equipment located on-site or brought in from off-site. When unconventional line-ups or hook-up connections are contemplated, consideration should be given to the availability of equipment necessary for easy use of these capabilities.

3.26 Accident management should be robust, which can be assured by the following:

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

(2) It should emphasize the use of components and systems that are not likely to fail in their expected operating regimes including 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 critical safety functions or limit challenges to fission product barriers;

(5) Specific consideration should be paid to accidents developing when the facility is in a shutdown state, as the containment barrier could be functionally lost and restoration difficult in some cases.

3.27 The capabilities of plant personnel to contribute to unconventional measures to mitigate accident challenges, including the behaviour and reliability of personnel under adverse environmental conditions, should be considered[32]. Where necessary, protective means should be provided and training should be implemented for the execution of such tasks. 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.

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 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 ACCIDENT MANAGEMENT STRATEGIES

3.29 On the basis of the vulnerability assessment and identified plant capabilities as well as the understanding of accident phenomena, accident management strategies should be developed for each individual challenge or plant vulnerability, in both the preventive and mitigatory domains.

3.30 In the preventive domain, strategies should be developed to preserve critical safety functions that are important to prevent fuel damage or prevent radioactivity release. These include achieving and maintaining sub-criticality, fuel cooling, coolant inventory and containment integrity.[33]

3.31 In the mitigatory domain, strategies should be developed with the objectives of:

- Terminating the progress of fuel degradation;
- Maintaining the integrity of the reactor vessel;
- Preventing re-criticality;
- Maintaining the integrity of the containment or any other confinement of fuel and

[32] Including performance when using protective clothing and breathing devices.

[33] An example of a preventive strategy is 'feed and bleed'. Another example is the use of non-permanent equipment for a prolonged station blackout caused by an extreme external event.

preventing containment bypass;

- Minimizing off-site releases of radioactive material;
- Achieving a long term safe stable state.

Strategies may be derived from 'candidate high level actions', examples of which are given in Appendix II of Ref [12].[34]

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.

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.[35]

3.34 Strategies should be prioritized taking into account plant status and the existing and anticipated challenges. The basis for the selection of priorities in accident management strategies should be documented. 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[36] 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[37];
- 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[38];

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[36] Examples of mitigatory strategies are: filling the secondary side of the steam generator to prevent creep rupture of the steam generator tubes; depressurizing the reactor cooling 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.

[35] An example is withholding water from the reactor cavity to extend the time to overpressure failure of the containment; this has the negative impact of possible core concrete interactions that may be irreversible. A further example is flooding the cavity, with the negative impact of possible occurrence of an ex-vessel steam explosion.

[36] For example, AC power, DC power, cooling water

[37] At shutdown, the Reactor Coolant system and containment might be open. Priority could be given to restoring containment integrity before any fuel degradation.

[38] 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 critical safety functions taking into account possible adverse conditions on-site. Support items such as fuel for non-permanent equipment should be available.

3.36 The implementation of specific mitigatory strategies should be triggered when certain parameters reach their threshold values. These parameters should be selected to be indicative of challenges to fission product barriers.

3.37 If strategies are considered that need to be implemented within a certain time window, the possibly large uncertainties should be taken into account in identifying such a 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 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[39]. Limitations that could arise from harsh environmental and radiological conditions should be taken into account.

3.40 Strategies which avoid or minimise the accumulation of large amounts of potentially contaminated water, including leakage from a failed containment should be preferred. Strategies for storing and remediating accumulated contaminated water should be considered in an appropriate manner.

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

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[39] 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.

DEVELOPMENT OF PROCEDURES AND GUIDELINES

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

3.43 Procedures and guidelines should be written in a user friendly way so that they can be readily executed under high stress conditions, and should contain sufficient detail to ensure the focus is on the necessary actions[40]. The procedures and guidelines should be written in a predefined format. Instructions to implementers should be clear and unambiguous, using consistent language and specific terms in accordance with established rules, preferably in a writer's guide.

3.44 Human factor aspects should include consideration of adherence to:

- Procedures and guidelines[41];
- Command and control structure.

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. [42]

3.46 The procedures and guidelines should contain as a minimum the following elements:

- Objectives and strategies;
- Potential negative consequences of the actions;
- Initiation criteria;
- The time window within which the actions are to be applied (if relevant);
- Monitoring of strategies;
- The equipment and resources (e.g. AC and DC power, water) required;

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[40] 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.

[41] This can result, for example in identifying the need for knowledge based versus rule based procedures and guidelines.

[42] For example, an immediate challenge to a fission product barrier, where 'immediate' means that there is no time or limited time for evaluation prior to decision making. Other examples are ´immediate actions`, to obtain a stable plant condition and work from there. Also such actions may be relevant before the technical support center (TSC) is available and operators must take action.

- Consideration of habitability for local action;
- Consideration of required personnel resources;
- Cautions and limitations;
- Local actions sheets (if relevant);
- Transition criteria and exit/termination conditions;
- Assessment and monitoring of plant response.

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

3.48 In the preventive domain, it may be possible to diagnose the accident on the basis of an appropriate procedure and plant alarms. Guidance 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[43]. Alternatively, the guidance can be fully linked to the observed physical state of the plant and so further diagnosis of the accident sequence is not necessary. Nevertheless, it may be appropriate to apply the diagnostic procedure at regular intervals to make it possible to return to the procedure specifically developed for the observed accident sequence. The guidance should be aimed at monitoring and preserving or restoring critical safety functions on the basis of the selected strategies.

3.49 Although in the mitigatory domain 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 control room staff[44] 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 signals is recommended.

[43] The diagnostic procedure should be applied at regular intervals in the evolution of the accident to evaluate the appropriateness of the diagnosis.
[44] For example, safety engineer, shift supervisor, etc.

3.51 Possible positive and negative consequences of proposed strategies should be specified in the guidelines as a basis for selection of strategies during the evolution of the accident.

3.52 The guidelines should be written in such a way that there is a possibility to deviate from an anticipated path where this might be necessary or beneficial[45]. However, this should be approved by the person with command and control authority.

3.53 Priorities should also be defined among the various procedures and 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 procedures and 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 Procedures and guideline sets that are implemented during accident management conditions should be integrated with each other to establish a comprehensive strategy for 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 from the preventive domain to the mitigatory domain. 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.[46]

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[47]. Any mitigatory guidance provided to 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.

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[45] Such flexibility may be necessary due 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.

[46] For example, fuel temperature rise and degree of fuel degradation as a consequence of anticipated time needed for identification of the transition point

[47] This situation can occur in cases where an event rapidly develops into a severe accident, or where the TSC cannot be activated within the time assumed in the guidance.

3.57 Proper transition from procedures to guidelines 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.[48] Safe stable state should be clearly defined and provisions to maintain the long term safe stable state should be specified.

3.60 Procedures and guidelines should be based on directly measurable plant parameters. Where measurements are not available, parameters should be estimated by means of simple computations and/or pre-calculated graphs. Use of parameters that could be obtained after carrying out complex calculations during the accident should only be contemplated if there is ample time for such calculations and there is reasonable assurance that the likelihood of error is reasonably low.[49]

3.61 It should be noted that various equipment may start automatically or change configuration upon certain parameters reaching pre-defined values ('set points').[50] Such automatic starts have usually been designed for events in the preventive domain. These automatic actions may be counterproductive in the mitigatory domain. Hence, all automatic actions should be reviewed for their impact in the mitigatory domain and, where appropriate, equipment should be inhibited from automatic start. Manual start of the equipment concerned should then be considered in the guidance.

3.62 Procedures and guidelines should contain guidance for situations where the preferred accident management equipment may not be available[51]. Alternate methods for achieving the same purpose should be explored and, if available, included in the guidance.

3.63 Guidance should be developed to diagnose equipment failure and to identify methods to restore such failed equipment to service. The guidance should include recommendations on the priorities for restoration actions. In this context the following should be considered:

- Importance of the failed equipment for accident management;

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[48] An example is given in Appendix VII of Ref. [15].

[49] When calculations and verifications can be carried out by proficient engineers using reliable, adequately qualified, computational tools.

[50] For example, like containment isolation devices.

[51] For example, because of equipment failure or equipment lockout. Note: equipment failure includes instrumentation failure..

- Possibilities to restore the equipment;
- 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 Recovery of unavailable equipment should be factored into accident management guidance. 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 accident management guidance should take into account the habitability, operability and accessibility of the 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[52] 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.

3.66 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.[53] 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 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?

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[52] Adequate lighting, temperature, chemical conditions if appropriate.

[53] Examples are provided in Appendix III of Ref. [15] or by the technical support guidelines (TSGs) developed by the BWR Owners Group.

3.68 Adequate background material should be prepared to support development of accident management guidelines. The background material should fulfil the following roles:

(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 basis and detailed description of steps in procedures and guidelines;
- The basis for specification of set-points used in the guidelines;

(2) It should provide a demonstration of compliance with the relevant quality assurance requirements;

(3) 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 responsible for the protection of the public and environment should be made aware of the potential need for transition to the mitigatory domain.

Multi-unit sites

3.70 In the case of sites where several units are in operation at the same site (multi-unit sites), the continued use of a unit that has not been affected should be taken into account in the accident management guidance. Special care 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. [54] There should be pre-defined criteria to decide whether or not the neighbouring units should be shut down.

3.71 When the neighbouring units at the near distance are in accident conditions, it should be considered to share information with neighbouring units for investigating whether expected dose rates and other environmental conditions due to damage propagation from neighbouring units may be affected to access operating areas for local actions.

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

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[54] For example, a cross-tie of heat removal systems from an unaffected unit may be useful for heat removal from the affected unit but this may require that the unaffected unit will remain at a certain predefined power level.

HARDWARE PROVISIONS FOR ACCIDENT MANAGEMENT

3.73 Changes in design should be evaluated where challenges to fission product barriers cannot be reduced to an acceptable level, or to reduce uncertainties in the analytical prediction of such challenges.

3.74 When additional equipment is supplemented to mitigate severe accidents, the ~~latter~~ equipment should preferably be independent with equipment and systems used to cope with design basis accidents.

3.75 Equipment upgrades aimed at enhancing preventive features of the plant should be considered as tasks with high priority. [55] For existing plants, providing non-permanent on- or off-site equipment (reasonably protected against external hazards) should be the preferred 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 for both the preventive and mitigatory domains. In particular, equipment upgrades which increase capability or margin to failure for the following functions should be taken into account:

- Monitoring key containment parameters such as temperature, pressure, radiation level, hydrogen concentration, and water level;
- Containment isolation in a severe accident, including bypass prevention;
- Ensuring the leak-tightness of the containment, including preservation of the functionality of isolation devices, penetrations, personnel locks, etc., for a reasonable time after a severe accident;
- Establishing or restoring the containment 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;
- Prevention and mitigation of dominant challenges, such as for;
  - containment overpressure and underpressure;
  - high-pressure core-melt scenarios;
  - reactor vessel melt-through;

[55] Examples are qualification of pressurizer valves for feed and bleed operation and additional redundancies on important safety systems (AC and DC power, available cooling water).

- basemat melt-through by molten corium.

3.77 Appropriate provisions should be available to remove the decay heat from the corium debris to an ultimate heat sink.

3.78 There should be multiple diverse accident management strategies and measures for mitigating challenges to containment integrity.[56] 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.[57]

3.79 When containment venting is possible, the accident management programme should provide guidance on its use to prevent uncontrolled loss of containment integrity and to mitigate releases of radionuclides causing long-term off-site contamination.

3.80 When containment venting is contemplated or directed in the accident management strategies, 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) An alternate means of venting the containment if rupture disks are installed that could inhibit venting when required. The preferred option should be to vent using a pathway that is likely to provide some reduction of fission product release;[58]
(4) The potential negative consequences of containment venting[59] should be assessed during the decision making process.

3.81 Accident management strategies should be developed for situations when DC power is lost during a long-term loss of all AC power.

3.82 Guidance should consider additional hardware provisions, including non-permanent on- and off-site equipment as a back-up measure where the existing[60] equipment is not anticipated to remain functional in the long-term[61] or could be disabled in case of station

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[56] Such measures can include special design provisions, or alternate use of equipment designed for other tasks.

[57] For example: connection points at different elevations may be considered to address flooding concerns.

[58] For example, filtered path or through a scrubber.

[59] For example, loss of water inventory.

[60] For example, decay heat removal

[61] In estimating the long term availability of components, the limited possibility – or impossibility – of maintenance should be taken into account (for example the long term running of highly contaminated residual heat removal pump without the possibility of maintenance for a long period).

black-out. In estimating the long-term availability of components the feasibility of performing maintenance or repairs should be evaluated and taken into account.

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 time-frame.

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 to prevent loss of fission product barriers.

3.85 Maintenance, testing and inspection procedures should be developed for equipment to be used in accident management taking into account the safety significance of such equipment.

INSTRUMENTATION AND CONTROL

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.

3.87 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[62,63] where possible. This should also be emphasized in drills and exercises.

3.88 The time needed for obtaining adequate information from plant parameters important for accident management should be taken into account when developing guidelines.

3.89 It should be confirmed that information needed for decision making during execution of accident management strategies can be obtained from the instrumentation in the plant. Such information should be available in all places where the evaluation and decision making is to

[62] Instruments may continue to provide information, such as trends, even if the readings are not accurate.

[63] For example, sometimes, a degree of malfunction of thermocouples depends on temperature, humidity, salt deposition and other environmental factors. Availability of the thermocouples can be evaluated by checking trends of neighboring signals and response to changes in cooling conditions such as the injection rate.

be made. Where instruments can give information on the accident progression in an indirect way, such possibilities should be investigated and included in the guidance.

3.90 All available information and background documentation on key 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 considered. Nevertheless, instrumentation may continue to operate well 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.[64]

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 beyond the design basis should be identified.

ANALYSES FOR DEVELOPMENT OF ACCIDENT MANAGEMENT PROGRAMMES

3.94 Besides activities performed as part of assessment of plant vulnerabilities and capabilities, the following guidance should be done:

3.95 Development and implementation of the accident management programme should be supported by appropriate computational analysis showing progression of representative

[64] Adequate information on additional means can be found in Ref [15].

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.

3.96 Utilization of suitable analysis methods with appropriate safety or risk metrics should be used to aid in decision making regarding plant upgrades. Consideration should be given to the fact that analysis in the field of severe accident management is usually not conservative but of best estimate analysis[65], and does not in itself create margins.

3.97 Address all significant sources of radioactive material in the plant, in particular the reactor core and spent fuel pools and occurrence of accidents in all relevant normal operational and shutdown states including shutdown states with open reactor or open containment barriers.

3.98 Address 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.[66] Multi-unit accidents should be analysed where applicable.

3.99 Address a sufficiently broad set of accident scenarios adequately covering potential evolutions of initiating events into design extension conditions and a comprehensive set of plant damage states. PSA Level 1 and 2, if available, in combination with engineering judgment should be used for selection of the scenarios.

3.100 Perform the selection of accident sequences in the following steps:

(1) A suitable categorization approach and a set of plant damage states should be developed. A categorization scheme should result in a list of groups of accident sequences including fuel degradation and melting, reactor vessel failure and containment boundary failure, and the associated severe accident phenomena.[67] The full list of plant damage states should be screened for the less important plant damage states in order to identify a limited set, considering contribution to core damage frequency and ensuring that all initiators are represented;

(2) One or more accident sequences for each plant damage state should be chosen, considering the total contribution to core damage frequency, the ability of the chosen sequence to represent other sequences in the same plant damage state, and the amenability of the chosen sequence to preventive accident management measures.

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[65] Accident analysis which is free of deliberate pessimism regarding selected acceptance criteria and uses a best estimate code with uncertainty analysis.

[66] Potential radiological consequence analysis of reactor accidents in term of doses.

[67] Many categorization schemes are possible. Level 2 PSAs contain such categorization schemes

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 Provide sufficient input for development of procedures and guidelines, in particular:

- choice of symptoms for diagnosis and monitoring the course of the accidents;
- identification of the key challenges and vulnerable plant systems and barriers;
- specification of set-points to initiate and to exit individual strategies;
- positive and negative impacts of accident management actions;
- time windows available for performing the actions;
- prioritisation and optimisation of strategies;
- evaluation of capability of systems to perform intended functions;
- expected trends in the accident progression;
- conditions for leaving SAM domain;
- computational aids development.

3.103 Provide 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.

3.104 Use generic plant analysis, if available, after assessment of its applicability for the specific plant.

3.105 Take into account the following aspects of accident scenarios that would lead to core damage and subsequent potential challenge to fission products barriers;[68]

- Sequences with no operator action or 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; and
- Potential cliff-edge effects.

3.106 Use best estimate computer codes, assumptions and data regarding initial and boundary plant conditions with appropriate consideration of uncertainties [69] in the determination of the timing and severity of the phenomena.

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[68] Note that selection of sequences that would, without intervention, lead to core damage, is an appropriate way of identifying accident scenarios for subsequent investigation of both preventive actions (taken before core damage) and mitigatory actions (taken after core damage).

[69] Uncertainties include those in understanding the phenomena that occur in the evolution of the accident as well as those

3.107 Use 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.

3.108 Evaluate and interpret all code results with due consideration given to code limitations and associated uncertainties.[70] The appropriateness of carrying out sensitivity analyses should be evaluated when computer code results are relied upon for making critical decisions.

3.109 Perform activities in accordance with basic rules for safety analysis as specified in the relevant IAEA Safety Requirement (see Ref. [7]).

PERSONNEL STAFFING AND NEEDS

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 multiple units can be affected simultaneously 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.

3.112 Acceptable working conditions (habitability) should be provided to plant and external support personnel in situations where the site is partially or totally isolated from continuous off-site support.

3.113 Shift turnover documents should be prepared.[71] 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.

3.114 Contingency plans should be developed for situations where accident management staff have been incapacitated or when outside support may be delayed.

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associated with SAMG actions

[70] For example, many codes have fixed heat transfer correlations (e.g. critical heat flux on a flat plate) based on an assumed geometry, whereas the actual event may involve geometry changes (e.g. shattering of corium debris), which create varying heat transfer surfaces that will enhance or degrade heat transfer and, hence, influence the actual temperatures attained.

[71] Information useful for the turnover document may be (but not limited to) severe accident related information such as: the severe accident sequence development, the procedures and guidelines in used at the time of the transition from the preventive to the mitigatory domain, the emergency teams involved in the mitigation, possible instrumentation inaccuracies and the recovery actions undertaken for unavailable systems.

3.115 Contingency plans, training, and guidance should be developed to help personnel cope with the emotional stress affecting personnel 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 off-site communication fails and only the on-site emergency response organization remains functional. The effects of a station black out on the communication equipment should be considered.

RESPONSIBILITIES, LINES OF AUTHORIZATION AND INTERFACES WITH EMERGENCY PREPAREDNESS AND RESPONSE

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 that deals with 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[72] should be established in the entire emergency response organization. The emergency response organization could include elements as depicted in Figure. 2. The emergency director (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 without the need for external authorization[73].

[72] For example, containment venting or use of un-borated water for injection to a PWR core and/or spent fuel pool (SFP)

[73] 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.

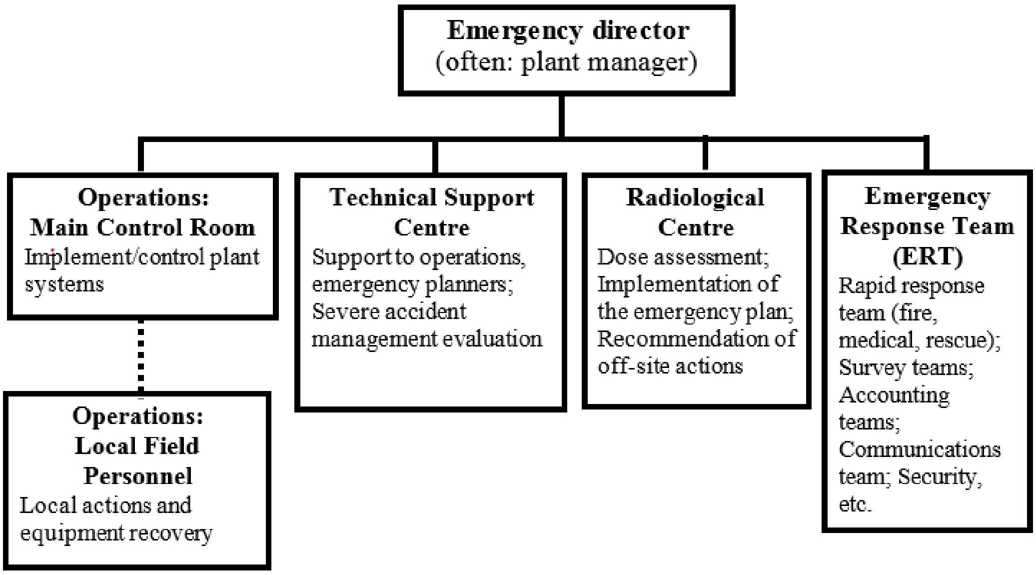

Figure.2 Example layout of the technical elements of the on-site emergency response organization

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 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.[74] Such contingency plans should identify an alternative authority and decision-maker.

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[74] Incapacitation could be the result of site isolation.

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

3.122 When transferring responsibilities, and decision making authority, impact of external hazards should be considered, in particular, when placing the decision making authority for accident management at both on-site and off-site locations.

3.123 In the preventive domain, decision making should be carried out by the control room staff[75]. For some situations, decision making may be placed at another appropriate level of authority.[76]

3.124 The decision making authority in the mitigatory domain 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 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 off-site 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 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 control room to the emergency director, the functions that remain in the control room and actions that can be decided upon by the control room staff independently of the emergency director should be specified.[77] As the control room staff is also responsible for the execution of the measures

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[75] The shift supervisor or shift manager, or a particular dedicated person, e.g. a safety engineer.

[76] For example, incapacitation of control room staff.

[77] These include activities that control room staff can carry out independently, such as maintaining support conditions (e.g. room

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 off-site persons is contemplated, it should be verified that such persons have the required background to efficiently exercise such authority. The impact of external hazards should be considered. In particular, a highly reliable communication network should be provided, together with guidance for the case of failure of the communication network.

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.

Technical Support Centre

3.130 Criteria for activation of the technical support centre should be unambiguous and clearly specified in plant procedures or on-site 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. When there are multiple support teams, their responsibilities and interfaces should be defined.

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 off-site) of the emergency response organization by performing evaluations and recommending mitigatory actions to the decision making authority.[78]

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[79] and a good understanding of the underlying accident phenomena[80]. The technical

cooling, service water) and responding to some alarms; activities that the control room staff should not do on their own (e.g. starting up major equipment) should also be specified

[78] For example, the intention to vent the containment at a certain moment and during a certain time on the basis of plant parameters may not be in line at that moment with proposed actions of the off-site emergency response organization.

[79] They should be able to get any information they need but that is not directly forwarded to them, e.g. through pre-established

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.[81] The mechanisms for calling on early support should be established, and the support capabilities should be verified on a periodic basis.

3.134 Rules for information exchange between the various teams of the emergency response organization 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 on-site and off-site emergency plans, should be specified. Oral communication between the technical support centre and the control 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 on-site and off-site teams, care should be taken that this communication does not disrupt the management of the accident at the plant.

3.135 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.[82]

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. The availability and use of such information should be considered in the development of guidelines. The plant information in the technical support centre should be recorded and monitored appropriately.[83] Where manual transfer of plant data is needed, this should preferably be done by a dedicated member of the technical support centre.

3.137 Extended loss of AC power should be considered in providing for communication between the control room, the technical support centre, and off-site facilities.

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protocols for contacting the control room.

[80] Their knowledge should be of such level that they are capable to understand the threat to important safety functions and fission product barriers also if complications arise or unexpected events occur that bring them outside pre-staged guidelines.

[81] If such support is not already part of the emergency response organization.

[82] 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).

[83] For example, by electronic data transfer.

3.138 The technical support centre should be designed to withstand external hazards.

Interfaces with emergency preparedness and response

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

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 described in this emergency plan with 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 The responsible authority should decide when to transition from emergency exposure situation to an existing exposure situation taking into account the need to protect individuals existing in long-term contaminated areas after a nuclear accident or a radiation emergency.[84]

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, to ensure that conflicts are resolved. This review might recommend changes to the emergency plan to eliminate such conflicts.

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

[84] Relevant information is presented in Ref, [21]. OECD/NEA forum for the Information System on Occupational Exposure (ISOE) established the Expert Group on Occupational Radiation Protection in Severe Accident Management (EG-SAM) for management of high radiation area worker doses from previous nuclear power plant accidents and effective use of personal protective equipment (PPE) and high-radiation area worker dosimetry for different types of emergency and high-radiation work situations.

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[85, 86]

3.145 Verification and validation processes should assess the technical accuracy and adequacy of the instructions, 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.). The validation process should demonstrate that the document provides the instructions necessary to implement the guidance.[87]

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 the use of a full scope simulator (if available), an engineering simulator 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 When 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.

3.150 Validation should be performed under conditions that realistically simulate the conditions present during an emergency and include simulation of other response actions,

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[85] Definition is from IAEA Safety Glossary (2007).

[86] More detailed information is provided in Ref [15].

[87] Text is from NEI-14-01 rev.0, “Emergency Response Procedures and Guidelines for Extreme Events and Severe Accidents”.

hazardous work conditions, time constraints and stress. Special attention should be paid to the use of portable and mobile equipment, when such use is contemplated, 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 [88] for assessing which kind of difficulties could exist for practical implementation of accident management measures, in particular in case of an external hazard.[89]

3.152 All equipment identified in the accident management programme, including non-permanent equipment, should be tested, or other reasonable means used, to verify that performance conforms to the requirements[90]. Testing should include the equipment and the assembled sub-system needed to meet the planned performance. Tests should include needed local actions, contingencies, and its proper connection to plant equipment, access to the site, off-site actions, multi-unit events, emergency lighting, etc., and the time needed for these actions. 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.[91]

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.

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[88] Inspection of local areas in a nuclear power plant where structures, systems, and components are physically located in order to ensure accuracy of procedures and drawings, equipment location, operating status, and environmental effects or system interaction effects on the equipment which could occur during accident conditions.

[89] For seismic-PRA and seismic-margin-assessment reviews, the walk-down is explicitly used to confirm preliminary screening and to collect additional information for fragility or margin calculations.

[90] Environmental conditions including temperature, pressure, humidity, radiation, chemicals will vary greatly with the time and location so that the equipment important to safety must be established for the most severe design basis accident.

[91] This includes independent review in Paragraphs 6.3-6.6 .of Ref [16].

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 education (classroom training), exercises and drills, supported by appropriate means, such as desktop training or adequate simulation tools.

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

3.157 Training should be developed using a systematic approach to training.[92] 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 on-site group and off-site group involved in accident management. Training should be commensurate with the tasks and responsibilities of the participants, taking into account appropriate technical level needed for each group. In-depth training should be contemplated 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[93], including operation of non-permanent equipment.

3.160 Training, including periodic exercises and drills should be sufficiently realistic[94] and challenging to prepare personnel responsible for accident management duties to cope with and respond to situations expected to occur during an event[95], including accidents occurring

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[92] Defined in Ref. [17].

[93] For example, high radiation, temperature, humidity, on-site damage.

[94] Drills should extend over a time period long enough not to unacceptably distort plant response, and allow to test transmission of information during shift changes.

[95] Special drills/exercises should be developed to practice operating shifts and TSC staff changeover and information transfer

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, use of non-permanent equipment (such as diesels or pumps) as well as repair of the equipment. Training material should address implementation of strategies under adverse environmental conditions, including those resulting from external hazards, under potentially high radiation situations and under influence of stress on the anticipated human behaviour.

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; 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.

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.[96]

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

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between different teams (e.g. turnover packages as are developed in several countries).

[96]Additional guidance for exercises/drills is presented in Ref [15].

should be paid to exercises that enhance the awareness of 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 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 in the plant design including the available non-permanent equipment or the operating organization on the accident management programme should be evaluated. 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.[97] 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 value for accident management by the operating organization/utility.[98]

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[97] Where a generic accident management programme is used, such processing should involve the vendor of the generic program.

[98] Exchange of information with peers should be used to provide continuous improvement of the accident management guidance. Such an exchange of information could be through, but not limited to, peers observing plant drills, and

3.172 Any update of the accident management programme should include, as appropriate, revision of background documents including supporting analysis used for their implementation[99].

MANAGEMENT SYSTEM

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 guidance on this subject presented in Refs. [16, 18, 19]. Where these should not be followed due to the uncertainties in the severe accident domain, the intent of the safety requirements should be followed to the extent practicable.

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.

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participation in exercises at other plants, the available IAEA review of accident management programme (RAMP) services, IAEA Operational Safety Review Team (OSART) mission, or World Association of Nuclear Operators (WANO) peer review.

[99] An example is a plant that has based its procedures and guidelines on a reference design or some other generic source of information, where then the originator of the procedures and guidelines on the reference design issues a revision of the accident management programme. Another example is an update of the PSA that identifies new accident sequences or existing sequences with a different weight, that were not a part of the basis of the existing accident management guidance.

4. EXECUTION OF PROCEDURES AND GUIDELINES

4.1 In case of an emergency, in particular one taking place in combination with an external hazard, plant staff should assess the global situation on-site and ensure that their emergency command and control structures are capable of directing responses in accordance with established procedure and guideline sets. If required, contingencies developed to re-establish command and control should be implemented. The assessment of the situation should include:

- Number of affected units;
- Control facilities functionality and habitability;
- Damage to essential structures and buildings;
- Availability of access to essential buildings and equipment; and
- Capability to communicate with off-site organisations.

4.2 Once the 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 control room staff should initiate actions under the SAMGs that apply until responsibility for recommending actions is transferred to another appropriate structure[100]. 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 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.

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) communication to the control room staff should preferably be carried out by a technical support centre staff member who is a licensed

[100] For example, the technical support center for most PWR nuclear power plants.

operator. A major step prior to recommending or attempting executing an action is to check feasibility of proposed actions.

4.5 The key 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[101] should be estimated at regular intervals, and should be communicated in a suitable form through proper channels to the organization responsible for further actions.[102]

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.

4.8 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 off-site 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 at the highest level in the Emergency Response Organisation.

4.9 A mechanism should be put in place to assign priorities in case of a conflict between planned releases and the off-site readiness. In principle, priority should be assigned to the actions that prevent major damage to the fission product barrier still intact.

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 always be commensurate with the time frame of the evolution of the accident.

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[101] Such as deliberate releases, or isolation of release paths.

[102] Such releases may be determined by consulting the PSA for the plant and inferring the relevant scenarios by interpretation of the plant parameters. Alternatively, fast running computer codes may be applied to analyse perceived scenarios and their most probable future evolution.

REFERENCES

[1] EUROPEAN ATOMIC ENERGY COMMUNITY, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, INTERNATIONAL MARITIME ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Fundamental Safety Principles, IAEA Safety Standards Series No. SF-1, IAEA, Vienna (2006)

[2] INTERNATIONAL NUCLEAR SAFETY ADVISORY GROUP, Defence in Depth in Nuclear Safety, INSAG-10, IAEA, Vienna (1996).

[3] INTERNATIONAL NUCLEAR SAFETY ADVISORY GROUP, Basic Safety Principles for Nuclear Power Plants, 75-INSAG-3 (Rev. 1), INSAG-12, IAEA, Vienna (1999).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Safety Glossary, Terminology Used in Nuclear Safety and Radiation Protection, 2007 Edition, IAEA, Vienna (2007).

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

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Nuclear Power Plants: Commissioning and Operation, IAEA Safety Standards Series No. SSR 2/2 (Rev1), IAEA, Vienna (to be published).

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

[8] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS OFFICE FOR THE COORDINATION OF HUMANITARIAN AFFAIRS, WORLD HEALTH ORGANIZATION, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSR Part 7, IAEA, Vienna (to be published).

[9] EUROPEAN COMMISSION, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, Safety Standards Series No. GSR Part 3, IAEA, Vienna. (2014).

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSR Part 7, IAEA, Vienna (2015).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Predisposal Management of Radioactive Waste General Safety Requirements, IAEA Safety Standards Series No. GSR Part 5, IAEA, Vienna (2009).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5), IAEA Nuclear Security Series No. 13, IAEA, Vienna (2011).

[13] INTERNATIONAL ATOMIC ENERGY AGENCY, Operational Limits and Conditions and Operating Procedures for Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-2.2, IAEA, Vienna (2000).

[14] INTERNATIONAL ATOMIC ENERGY AGENCY, Development and Review of Plant Specific Emergency Operating Procedures, Safety Reports Series No. 48, IAEA, Vienna (2006).

[15] INTERNATIONAL ATOMIC ENERGY AGENCY, Implementation of Accident Management Programmes in Nuclear Power Plants, Safety Reports Series No. 32, IAEA, Vienna (2004).

[16] INTERNATIONAL ATOMIC ENERGY AGENCY, Guidelines for the Review of Accident Management Programmes in Nuclear Power Plants, IAEA Services Series No. 9, IAEA, Vienna (2003).

[17] INTERNATIONAL ATOMIC ENERGY AGENCY, The Management System for Facilities and Activities, IAEA Safety Standards Series No. GS-R-3, IAEA, Vienna (2006)

[18] INTERNATIONAL ATOMIC ENERGY AGENCY, Experience in the Use of Systematic Approach to Training (SAT) for Nuclear Power Plant Personnel, IAEA-TECDOC-1057, IAEA, Vienna (1998).

[19] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of the Management System for Facilities and Activities, IAEA Safety Standards Series No. GS-G-3.1, IAEA, Vienna (2006).

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

[21] ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT NUCLEAR ENERGY AGENCY, Occupational Radiation Protection in Severe Accident Management, NEA Report No. NEA/CRPPH/R(2014)5, OECD NEA (2015).

ANNEX I - Insights on the use of SAMGs in France Plants

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 or subsequent performance of a whole set of immediate actions by main control room (MCR) personnel. 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 contemplated, 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 contemplate 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

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)[103] 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;
- Activation of the containment spray system to prevent containment over-pressurization and remove thermal energy from the containment atmosphere[104];
- 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.[105]

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[103] Dedicated lines in case of European Pressurized Reactor

[104] 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.

[105] For limiting the risk of Hydrogen combustion in very specific stuations

ANNEX II - Insights on the use of SAMGs in German Plants

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

In addition, to keep abreast with the international community, the development of SAMGs has been started in 2010, and was fully completed end of 2014. In addition, to keep abreast with the international community, the development of SAMGs has been started in 2010, and full completion is contemplated for 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 contemplated 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 contemplated 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 contemplated action.

SAM guidelines neither contemplate 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 contemplated 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.

ANNEX III - Insights on the use of SAMGs in US Plants

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 SAM, 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 SAM, 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 SAM 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 SAM guidelines have priority upon EOPs. In the B&WOG approach, no re-entrance in EOPs is contemplated. All Owners Groups address the pros and cons of contemplated actions, with a level of detail adapted to their needs. The WOG has adopted tables with the pros and cons of each contemplated 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 contemplated, 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 contemplated in these systems.

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