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Guidelines for the review of accident management programmes in nuclear power plants

Reference document for the IAEA safety service missions on review of accident management programmes in nuclear power plants

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GUIDELINES FOR THE REVIEW OF ACCIDENT MANAGEMENT PROGRAMMES
IN NUCLEAR POWER PLANTS:
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FOREWORD

Many Member States operating NPPs are at present developing accident management programmes (AMPs) aimed at the prevention and mitigation of severe accidents. Such developments are in compliance with a revised set of the IAEA Safety Standards Series, in particular with Safety Requirements on Design, on Operation, and on Preparedness and Response for a Nuclear and Radiological Emergency. However, the level of implementation varies significantly between NPPs. The exchange of experience and best practices can contribute considerably to the quality and facilitate the implementation of AMPs at the plants.

Various IAEA activities assist countries in the area of accident management. Several publications have been developed that provide guidance and support in the establishment of accident management at NPPs. Various technical meetings and workshops are also organized to provide a forum for presentations and discussions and to share experience in the development and implementation of accident management at individual NPPs.

The Safety Report on Development and Implementation of Accident Management Programmes in Nuclear Power Plants has a special role among the IAEA guidance publications. It provides, in the most applicable fashion, a description of the elements which should be addressed by the team responsible for preparation, development and implementation of a plant specific AMP at a NPP. The issues addressed include formation of the team, selection of accident management strategies, safety analyses required, evaluation of the plant systems performance, development of accident management procedures and guidelines, staffing and qualification of accident management personnel, and training needs. The report is intended to facilitate the work to be done by the NPP operators, utilities and their technical support organizations, but it can also be used for the preparation of the relevant national regulatory requirements.

The Safety Report served as a background for the IAEA Safety Service on Review of Accident Management Programmes (RAMP), which is offered to Member States to perform an objective assessment of the status in various phases of accident AMP implementation, compared with international experiences and practices. This publication is intended to give guidance on how a RAMP review is organized and conducted. Necessary background information for reviewers is selected and included. It also describes the steps needed to prepare the review. It is therefore useful for both developers and reviewers of AMPs in NPPs.

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CONTENTS

1. INTRODUCTION

1.1. Background

Consideration of beyond design basis accidents (BDBAs) of the nuclear power plant (NPP) is an essential component of the defence in depth approach used in nuclear safety. BDBAs have very low probabilities, but may have significant consequences resulting from the nuclear fuel degradation. A set of actions taken during the evolution of an event sequence towards BDBA

- to prevent the escalation of the event into a severe accident
- to mitigate the consequences of a severe accident
- to achieve a long term safe stable state

is termed as ‘accident management’. Accident management programme (AMP) comprises plans and actions undertaken to ensure that personnel with responsibilities for accident management are adequately prepared to take effective on-site actions to prevent or to mitigate the consequences of a severe accident and, when deemed necessary, to plan and implement plant modifications. In accordance with principles of defence in depth, accident management provisions should take place in any case, even if all provisions within the design basis are adequate.

The IAEA safety service described in this publication is intended to facilitate development and implementation of an AMP into operation of a NPP. Review of AMP has been since long time a part of another IAEA safety service, namely Operational Safety Review Team (OSART) [1]. It is considered that separate safety service devoted to AMP will cover more deeply the issue under consideration. Nevertheless, it is not intended to replace review of accident management as a part of overall review of NPP operational safety aspects within the framework of OSART missions.

A revised set of the IAEA Safety Standards and other safety related publications forms the basis for this new safety service. Following publications are mostly relevant:

- Safety of Nuclear Power Plants: Design [2];
- Safety of Nuclear Power Plants: Operation [3];
- Preparedness and Response for a Nuclear or Radiological Emergency [4];
- Safety Assessment and Verification for Nuclear Power Plants [5];
- Operational Limits and Conditions and Operating Procedures for Nuclear Power Plants [6];
- Basic Safety Principles for Nuclear Power Plants [7];
- Development and Implementation of Accident Management Programmes in Nuclear Power Plants [8];
- Accident Analysis for Nuclear Power Plants [9];
- TECDOC on Training Material and Technical Support for AMP Courses and AM Staff Training [11].

In particular, the Safety Report [8] describes AMP and makes suggestions on its preparation, development and implementation in any individual NPP and represents the main basis for the safety service presented in this publication. The safety service is intended for use primarily, but not exclusively for existing NPP, i.e. for the plants which are either in operation or under construction. IAEA Safety Glossary [12] provides an explanation of the terminology used in this publication.

1.2. Objectives of the IAEA accident management safety services

Similarly as for other IAEA safety services, the objectives of accident management safety service are to assist the Member States in ensuring and enhancing the safety of NPPs. In particular, the objective is to assist at the utility and NPP (i.e. licensee) level in effective plant specific AMP preparation, development and implementation. However, assistance can also be provided to the regulatory body in its reviewing of AMPs. Objectives of the safety service can be summarized as follows:

- To explain to licensee personnel principles and possible approaches in effective implementation of AMP based on experience world-wide;
- To give opportunities to experts from the host plant to broaden their experience and knowledge in the field;
- To perform an objective assessment of the status in various phases of AMP implementation, compared with international experience and practices;
- To provide the licensee with suggestions and assistance for improvements in various stages of AMP implementation.

1.3. Options of IAEA accident management safety services

The objective of the IAEA safety services is to offer two options to respond to individual requirements. These options include missions to review accident analysis needed for accident management and missions to review the whole AMP.

- **Review of accident analysis for accident management (RAAAM):** this review is intended to check completeness and quality of accident analysis covering BDBA and severe accidents. The review should be typically performed prior to use of accident analysis for development of AMP. It is considered that 2 experts and 1 IAEA team leader in one-week mission can perform the review. Detailed guidelines for review of analysis are provided in Section 2. Reference is also made to another IAEA Safety Report [2], which is devoted to guidance for accident analysis of nuclear power plants (NPPs).

- **Review of AMP (RAMP):** this review of AMP, which is in particular appropriate prior to its implementation, is intended to check its quality, consistency and completeness. The review of accident analysis as described in the previous paragraph is a part of the overall review. The review of AMP can be performed by the licensee personnel, or by an external review team. It is considered that a group of 4 invited experts and one team leader (IAEA staff) during one-week mission will be capable to perform the task. Such composition of the team is sufficient, if detailed review of accident analysis as described in the previous bullet was done separately as a different task, or e.g. within the framework of review of level 1 or level 2 PSA study. If this is not the case, than two more experts should be included in the team to take care of the accident analysis. Methodology for the RAMP mission is described in Section 3 of this publication.

1.4. Purpose and scope of the guidelines

IAEA safety services are provided by a team of carefully selected international experts. The purpose of this report is to give guidance on the preparation, execution and reporting of IAEA missions devoted to review of the AMP or its components. The report should be primarily used as guidance for the review team members. However, it will be also of assistance to operators and regulators in preparing, developing and implementing AMP and in performing their internal review or regulatory review.

1.5. Structure of the guidelines

The present publication consists of four main sections, and two annexes. Section 2 of this publication is devoted to review of the accident analysis required for AMP implementation. This part is considered separately due to its importance for development of AMP, and due to its applicability in various stages of AMP preparation and development, even before development of AMP itself. The review of all aspects of accident analysis is covered in this section. Section 3 gives advice how to perform a review of quality, consistency and completeness of the overall AMP. Section 4 describes formal arrangements for preparation and conduct of the review by the IAEA expert team. Annex 1 gives an example for basic structure of the final review report. Annex 2 provides an example of agenda for a one-week review mission.

2. REVIEW OF ACCIDENT ANALYSIS FOR ACCIDENT MANAGEMENT

2.1. Objectives of the review

The prime objective of the review is to assess the completeness and quality of accident analysis performed for BDBA and severe accidents. The review will focus on the following areas: selection of accident sequences, selection of analytical tools, analysis of accidents without operator action, analysis of various preventive and mitigative accident management measures (including use of existing and new equipment) performed by plant staff, and quality assurance (QA) in accident analysis. As the whole AMP development process, accident analysis follows the best estimate approach.

In BDBA and severe accident analysis, a large range of physical phenomena has to be taken into account. Although the understanding of these phenomena has been considerably improved in the past, uncertainties still exist. There are also uncertainties associated with (necessarily simplified) code models and correlations, with representing the real plant, and with measuring or monitoring the actual plant status. These uncertainties have to be considered in the evaluation of analysis results.

It is important to note that the scope of the proposed review process depends on the approach to accident management. Where generic analysis, procedures and guidelines exist, attention is being placed on their application to specific plant conditions. This differs from a situation where accident analysis for accident management is started from scratch. It is realised that the proposed review process mainly addresses utilities at an early stage of the AMP development.

It should also be noted that accident analysis is only one part, however important, of the development of AMPs. Incomplete analyses do not prohibit initial phases of AMPs be developed.

2.2. Reference material

The review will be based on technical documents/reports that are made available (in English) to the reviewer. It is understood that a complete set of the reference material may be too voluminous in order to be studied in detail by the experts before the review. In addition, some of the documents may be restricted/classified and can be made available only for the review period on-site. Reference material should therefore be divided in basic material that is needed in advance of the review mission, and more specific material to be provided during the review mission.

Advance reference material should contain the following:

- Basis for the selection of accident sequences and their categorisation;
- Characteristics of computer codes used;
- Summary report on analysis of accidents without operator action;
- List of symptoms used for preventive and mitigative actions; and
- Summary reports on analysis with operator actions.

Material to be made available during the review mission comprises:

- Summary reports on PSA level 1 and level 2, if available or other relevant documents showing the plant vulnerabilities;
- Justified list of the selected accident sequence classes;
- Engineering Handbook and Database for the analysis, with references to sources of data;
- Justification of the applicability of the computer codes selected for analysis;
- Full reports on analysis without operator actions, preventive and mitigative measures analysis;
- Plant emergency operating procedures (EOPs);
- Quality assurance procedure for accident analysis and prove of its application.

2.3. Course of the review

Depending upon scope and degree of completion of accident analysis for accident management, the review team would typically consist of 2 invited experts and one IAEA technical officer leading the review. The actual review is organised in the form of a workshop with flexible working groups consisting of review team members and members of the team responsible for accident analysis for accident management. During the review different subject areas are investigated and the results compared with expectations. This process is outlined below.

2.3.1. Selection of accident sequences

Analysis is available of sequences, which, without operator intervention, would lead to core damage, core melt, vessel failure, containment failure and release of fission products (FPs) to the environment. Since the number of sequences leading eventually to the release of

FPs to the environment is virtually infinite, a method to select accident sequences, or classes of sequences, was chosen. An accident sequence classification was developed which involves identification of a suitable categorisation scheme (note that a complete PSA level 2 would replace this step). Key questions to be addressed in the review:

1. Was adequate use made of results of PSA level 1?

2. Is there additional information used for the accident sequence categorisation process, as e.g.
   - design specifications;
   - equipment technical specifications;
   - operational experience;
   - accident precursors;
   - design specific experimental results;
   - severe accident research; and
   - information from similar plants?

3. Have plant specific severe accident phenomena been considered in the selection process?

4. Have accident sequence classes been chosen which focus on risk significant accidents?

2.3.2. Information needed for analysis

A collection of plant documentation exists which was used for the preparation of computer code(s) input data. The database contains all necessary information such as geometry, thermal-hydraulic parameters, control and safety systems' characteristics, set points, and includes drawings and other graphical documents. An Engineering Handbook exists that describes the process of converting the plant's database into a computer input deck. Issues to be evaluated are:

1. Which methodology was applied and what simplifying assumptions and calculations were made to convert technical plant data to code input deck?

2. Are modelling assumptions adequately explained and described?

3. Were input data verified by review and crosschecking by qualified individuals and groups that were not involved in the input deck development process?

4. Is verification appropriately documented?

2.3.3. Selection of analytical tools

Accident analyses are available through calculations with complex computer codes. Best estimate codes were selected for BDBA and severe accident analysis. Validated codes were chosen to the extent possible which adequately describe the physical processes for given phases of accidents. Limitations of codes to adequately simulate physical processes and accident phenomena are understood. Issues that need to be addressed:

1. Are the codes capable to adequately model the physical phenomena in question?

2. Do the physical models adequately represent plant specific behaviour?

3. Were the applicability range of models and correlations identified?

4. Was detailed user guidance available and actually used?

5. Is the personnel qualified for use of the codes?

6. Has a code qualification programme performed and documented?

2.3.4. Analysis without operator action

Based on a justified accident sequence selection process, accident were analysed to understand plant response to BDBA and severe accidents, to understand which accident phenomena are important for the plant in question, to understand and rank challenges to FP boundaries, and to provide a sound basis for the investigation of preventive and mitigative measures:

1. Was the timing of key events in accident progression documented?

2. Are trend plots of key parameters available?

3. Are the analysis results physically reasonable?

4. Have vulnerabilities of the specific design been identified and reported, and ranked according to their importance?

5. Have major challenges to FP boundaries been identified and reported?

6. Were accident phenomena important to the specific plant identified?

7. Have the mutual dependencies of the key phenomena been appropriately identified?

8. Is reporting of the analysis results complete and concise?

2.3.5. Evaluation of capabilities and limitations of existing equipment

Analyses are available to evaluate the capabilities of equipment to perform, under accident conditions, as required for the success of individual strategies. Depending on the accident management approach, use of existing equipment outside its design range and margins was assessed, or new equipment is being considered in cases where available equipment is found to be ineffective to facilitate accident management actions. Review of the following issues is recommended:

1. Has the operability of existing equipment under accident environmental conditions been assessed?

2. Is there justification of operability of existing equipment outside its design range?

3. Is additional/new equipment dedicated to accident management adequate?

2.3.6. Identification and analysis of preventive measures

Based on plant vulnerabilities and important accident phenomena, accident sequences were selected to analyse, with due consideration of capabilities and limitations of existing systems and plant equipment, possible preventive measures to prevent or delay the onset of core damage. In cases were generic analyses and EOPs already exist, they were transformed for plant specific application. Measurements of needed parameters for preventive actions' initiation can be accomplished with existing, upgraded or newly installed instrumentation. The effectiveness of preventive measures has been analytically demonstrated, EOPs were developed and validated:

1. Do the areas selected for studying preventive measures reflect findings of accident sequence analyses without operator intervention?

2. Have identified important accident phenomena been considered in the analysis?

3. Were the same input deck and version of computer code(s) used as for analyses without operator intervention? Have changes, if any, in the plants' database and the use of different versions of a code, been justified and documented?

4. Are the results of the analysis completely and concisely reported?

5. Was analysis performed to determine that symptoms selected for activating measures in key areas of preventive accident management can be used for the whole range of accident sequences chosen for analysis?

6. Are sensitivity studies available and documented with varying values of the symptom(s) that indicate accidents occurring outside the design?

7. Are sensitivity studies available and documented with varying time windows for initiating (and stopping) preventive actions?

8. Is there proof that operator action cannot aggravate the situation?

9. Are the preventive strategies reflected in EOPs?

2.3.7. Identification and analysis of mitigative measures

In case that preventive accident management measures are not successful, subsequent mitigative measures are needed to contain FPs in the reactor vessel and/or the containment, and to delay or minimise releases. Accident sequences were selected to analyse, with due consideration of capabilities and limitations of existing systems and plant equipment, possible measures to mitigate the consequences of core damage. Priority is given to prevention of vessel failure, prevention of containment failure, and minimising FP release. Where generic analyses and SAMG exist, transformation to plant specific requirements was carried out. Measurements of needed parameters for mitigative actions' initiation can be accomplished with existing, upgraded or newly installed instrumentation. The effectiveness of mitigative measures has been analytically demonstrated, SAMG were developed and validated. Key issues to be addressed are:

1. Do areas selected for mitigative measures studies reflect findings of accident sequence analyses without operator intervention and with preventive measures?

2. Have the identified important accident phenomena been considered in the analysis?

3. Were the same input deck and version of computer codes used as for analyses without operator interventions? Have changes, if any, in the plants' database and the use of different versions of a code, been justified and documented?

4. Is the report on the analysis complete and concise?

5. Was analysis performed to determine that symptom(s) selected for activating measures in key areas of mitigative accident management can be used for the whole range of accident sequences chosen for analysis?

6. Have sensitivity studies been performed and documented with varying values of the symptom(s) that indicate accidents occurring outside the design range?

7. Have sensitivity studies been performed and documented with varying time windows for initiating (and stopping) mitigative actions?

8. Are mitigative strategies reflected in severe accident management guidelines (SAMGs)?

2.3.8. Quality Assurance in accident analysis

Accident analysis was subject to formally established QA procedures:

1. Are QA procedures in agreement with established rules?

2. Has the production of the Database and the Engineering Handbook been in line with the established QA procedures?

3. Have all contradictions been satisfactorily resolved?

4. Was the input deck verified, and how was it validated?

2.4. Results of the review

The results should be documented in a report containing the major findings regarding the individual review steps outlined in section 2.3. It should also contain conclusions and recommendations with respect to:

- appropriateness of accident sequence selection;
- qualification of analysis tools;
- correctness of input data, including correct consideration of NPP equipment;
- identification and analysis of preventive and mitigative accident management measures; and
- QA in accident analysis.

The report is expected to provide, if applicable, proposals for further improvement of accident analysis as regards its extent and quality.

3. REVIEW OF AMP

3.1. Objectives of the review

The objective is to review the comprehensiveness, consistency, and quality of the AMP. The comprehensive AMP should also consider material and human resources, interrelation with other plant activities and emergency organization and qualifications and training of the plant personnel.

AMP is a large undertaking, which comprises plans and actions to ensure that the plant and its personnel with due responsibilities are adequately prepared to perform effective on-site actions to prevent and to mitigate the consequences of a severe accident. Typically, the AMP is not described by a single document, but rather by a set of documents. The most important outcome of the AMP development is a set of accident management procedures, which consist of EOPs and SAMGs or their equivalent, together with their background reports for justifications and explanations. There are also many other related documents, such as emergency plans, QA programmes, description of the plant physical protection, PSA studies and others to be included in the review.

The review follows the main steps indicated by the reference IAEA Safety Report [1] on the preparation, development and implementation of the AMP. The structure of the review is to check first that all the aspects of the main steps are addressed properly. Section 3.3 contains questions and issues to be reviewed on each main step. The review of accident analyses, if not done earlier separately, can be performed in parallel to the stepwise review by the analysis experts.

The second phase of the review is screening of the completeness of the AMP using the method of objective trees (see Section 3.4).

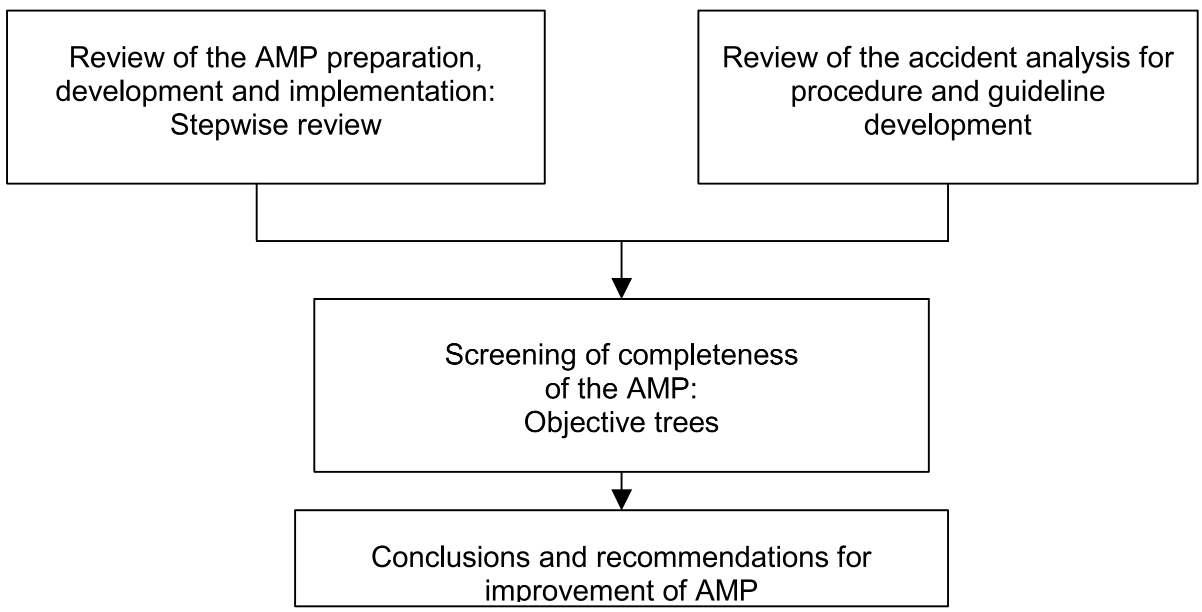

Fig. 1. Conduct of the AMP review.

3.2. Reference material

Typical documents to be submitted (in English, translated if necessary) prior to or to be made available during the review should contain all necessary background material and they are listed in the following. The specific content of the documents may vary owing to national practices.

The advance material should contain the following:

- Relevant regulatory requirements;
- Description of the NPP systems configuration;
- Summary report on PSA level 1 and, if available, level 2 or another documents showing plant vulnerabilities;
- List of symptoms used for preventive and mitigative actions;
- Tasks and tools of the technical support centre (TSC);
- Overview of the EOPs and SAMGs;
- Overview of computational aids (CAs);
- Overall description of the AMP;
- Results of previous peer reviews relevant to the accident management; in particular, this also includes peer reviews of PSA level 1 and 2 studies, if available.

Material to be made available during the review mission comprises, as appropriate:

- Justified list of the selected accident sequence classes and their categorization;
- All the documents needed for review of accident analysis in support of accident management (see Section 2.2);
- EOPs;
- SAMGs;
- List of equipment considered in accident management;
- Documents on qualification of equipment (including instrumentation) considered in accident management;
- Training programmes for AMP personnel, including description of software tools;
- QA programme for operation;
- On-site and off-site emergency plans including emergency organization (including classification of emergencies, activation of the response organization, conduct of in-plant assessment and mitigative (e.g., fire fighting, damage control) operations and taking urgent protective actions);
- Documentation on the plant physical protection related to accident management;
- Programmes and results of emergency drills.

3.3. Course of the stepwise review

One phase of the review process deals with performing a stepwise review of the AMP. This review should cover the following steps, which are important in the preparation and development of AMP.

1. Selection and definition of AMP;
2. Accident analysis for AMP;
3. Assessment of plant vulnerabilities;
4. Development of severe accident management strategies;

5. Evaluation of plant equipment and instrumentation performance;
6. Development of procedures and guidelines;
7. Verification and validation of procedures and guidelines;
8. Integration between AMP and plant emergency arrangements;
9. Staffing and qualification;
10. Training needs and performance; and
11. AMP revisions.

In the following sections, each of these areas is considered in turn, and a checklist of questions for the reviewer is provided. The checklists are based on the programme development and implementation approach described in [1].

3.3.1. Selection and definition of AMP

It is necessary to define at the start of the project the basic principles to be adopted in the programme, the scope of the programme, its links to other projects, to any upgrade policy, and compliance with any national regulatory requirements. The checklist identifies some key aspects of the basic definition of the AMP:

1. Has the degree to which the implementation of the AMP may generate requirements for equipment upgrades been specified?

2. Have national requirements been addressed?

3. Is there a clear distinction between preventive and mitigative parts, and their respective objectives?

4. Is the approach fully symptom based?

5. Is the approach (predominantly) independent of understanding the accident progression and therefore not requiring successful diagnosis of the event?

6. Have the entry and exit conditions, and the transitions between EOP and SAMG (if applicable) been defined, and existing EOPs modified to reflect them?

7. Has the transition between preventive and mitigative procedures/guidelines been clearly defined, including whether or not there is any overlap or simultaneous usage?

8. Has the acceptable plant end state configuration (for example a ‘controlled stable state’) been defined?

9. Has appropriate attention been given to the choice of guidelines versus procedures for both the preventive and mitigative parts of the AMP?

10. If a generic approach has been used, has it been appropriately evaluated and assessed for applicability to the plant design in question?

3.3.2. Accident analysis for AMP

Accident analysis serve as an important means to ensure that the guidance prepared is appropriate for the plant, in terms of identifying potential challenges, verifying applicability of strategies, and supporting implementation activities such as guideline validation. Requirements for analytical information will be generated at all three main phases of the programme (preparation, development and implementation), as discussed more fully in [1]. The checklist provides key questions related to each of these phases. Note that a detailed review of supporting accident analysis (as described in Section 2) may be performed in parallel with this step-by-step review.

General:

1. Where analysis has been performed, have appropriate tools and models (with sufficient range of applicability) been used to perform the analysis?
2. Has due consideration been made of the uncertainties in the predictions of the analytical models? What practical impact did this have on the procedures and guidelines?
3. Has analysis been performed on a 'best estimate' basis?

Preliminary analysis:

1. Was an initial review of available background analyses and other supporting information performed at the beginning of the development project?
2. Was the review able to conclude that sufficient background information already exists to identify plant specific vulnerabilities, nature and importance of potential challenges to FP boundaries, timing of challenges, parameters which can be used as symptoms, potential strategies to manage the accident, and in general to understand well the plant specific response to accident situations? If not, was an appropriate programme of work performed to develop such a technical basis?
3. Did the background information also indicate what the plant response would be to proposed strategies?

Development phase analysis:

Are the following aspects of the AMP development backed up by analysis:

- confirmation of choice and optimisation of strategies
- setpoint calculations
- use of systems to perform specific duties
- choice of key symptoms
- CA development
- any recommendations for equipment or instrumentation upgrades?

Implementation phase analysis:

Was any analysis performed in support of the validation programme appropriately defined and performed?

3.3.3. Assessment of plant vulnerabilities

Identifying design specific vulnerabilities is the first step to developing accident management strategies:

1. Has a systematic plant specific identification of the plant’s vulnerabilities been performed?

2. Was a suitable and appropriate technical basis (including background documentation and analyses) used to perform the identification of vulnerabilities?

3.3.4. Development of severe accident management strategies

High-level strategies are developed to deal with the potential challenges:

1. Has an appropriate process for the identification and evaluation of potential strategies been followed (for example as defined in Ref. [8])?

2. Has an appropriate set of criteria or safety objectives been defined in order to allow for grouping of strategies in terms of their urgency, etc.?

3. Have the strategies been systematically identified, evaluated for potential effectiveness, and evaluated for potential negative impacts?

4. If the programme is based on a generic approach, has an assessment of differences between the actual and generic reference plant designs been made, and applied to an assessment of the applicability of generic strategies?

5. Has due consideration been taken of the possibility and effects of interactions between different strategies?

6. Have rules of usage been developed describing among others the selection of priorities, the way the various strategies are implemented, and whether to start already a new strategy before a preceding one is completed?

3.3.5. Evaluation of plant equipment and instrumentation

Issues related to the needs for, the potential availability of and the limitations associated with all types of equipment and instrumentation used during the accident must be addressed:

1. Has a systematic review of plant specific systems capabilities (including use of systems for purposes outside their original design basis) been performed, and have the results been specifically reflected in the procedures/guidelines?

2. Has the likely availability of this equipment during a severe accident been addressed?

3. Have any limitations (including power supply, cooling media) associated with operating the equipment been identified and addressed? E.g. can interlocks be removed in a user friendly way?

4. Have possible alternative ways to implement a given strategy been identified?

5. Have temporary measures (connections, portable equipment) also been considered?

6. Have the instruments needed been identified in an easily usable way? Is the list comprehensive (systematically identifying demands made in the guidelines)?

7. Have these instruments been assessed for their likely availability during a severe accident? It is known in which direction instruments may deviate when exposed to harsh environmental conditions? Have the conditions under which the instrumentation may be misleading been identified in the guidance?

8. Have possible alternatives to the preferred instruments been identified and prioritised? Has it been assured that instrument indicators are backed up by alternative ones wherever this is feasible?

9. Have the necessary arrangements been made to ensure that the instrument data is available to the SAMG users?

10. Have the instrument ranges been verified as adequate?

11. Have instrumentation limitations been clearly identified in the guidelines or in other easily accessible documentation?

12. Have the required CAs been identified based on specific needs, and developed?

13. If equipment dedicated to severe accident management has been installed, has it been qualified for the expected accident conditions?

14. For multi-unit sites, have the implications for the unaffected unit(s) been addressed?

15. For multi-unit sites, has the use of systems or other capabilities from the unaffected units been addressed?

3.3.6. Development of procedures and guidelines

The basic structure and the high level strategies are detailed in the development of procedures or guidelines:

1. Has a consistent approach to procedure and guideline writing been adopted (language, use of specific terms, etc.)? Has a 'writers guide' been followed?

2. Has guidance been prepared for all involved parts of the organization (e.g. operators, safety engineer(s), TSC?

3. Has user-friendliness of guidelines and procedures been properly addressed, in particular regarding the assessment of availability and capability of plant systems to perform the different strategies?

4. Is the text and supplementary diagrams in the guidelines and procedures easy to read?

5. Have the long-term implications or concerns of implementing the strategies been considered?

6. Is not only point-value information from instrumentation asked for, but also trend information?

7. Has it been verified that access to equipment will be possible for local actions required by the guidelines?

8. Have requirements and means to override or block automatic protection system signals or interlocks been identified?

9. Have potential confusions due to translation between languages been addressed?

10. Has background information been prepared which is plant specific, comprehensive and clear?

11. Has the need to produce revisions of the guidelines and background information been considered within the structure of the material?

3.3.7. Verification and validation of procedures and guidelines

Review, verification and validation activities are required to ensure the overall quality and usability of the final guidance material:

1. Were the plant specific procedures and guidelines fully and independently reviewed, in accordance with the applicable QA programme, during their development?
2. Do the setpoints and the guidance as defined reflect the present state of the art and are they in line with the technical boundaries of the plant?
3. Has there been an independent external review?
4. Has it been verified that the procedures/guidelines represent technically correct interpretations of the high level strategies and are capable of achieving their objectives?
5. Has an appropriate validation programme been developed and implemented?
6. Did the scenarios chosen for use in the validation cover a wide range of the procedures/guidelines?
7. Did the validation test the organizational aspects of severe accident management, especially the roles of the evaluators and decision makers?
8. Did the validation address the communications between the different teams involved?
9. Was an appropriate simulation method chosen for validation (simulators, computer simulation, table top exercise, etc.)? Have the accident management procedures been tested under conditions that realistically simulate the conditions present during an emergency to include: simulations performance of other response actions, hazardous work conditions, time constraints and stress?
10. Was the necessary plant specific input provided to the validation (for example pre-analysis of accident scenarios)?
11. Were the results and conclusions of the validation documented?
12. Were the lessons learned from validation fed-back into the procedures and guidelines?

3.3.8. Integration of AMP and plant emergency arrangements

Organizational aspects, especially definition of lines of responsibility, are covered by a review and potential additions to the plant's emergency arrangements (Note: Arrangements are the integrated set of infrastructure elements necessary to provide the capability for performing a specified function or task required in response to a nuclear or radiological emergency. These elements may include authorities and responsibilities, organization, co-ordination, personnel, plans, procedures, facilities, equipment or training):

1. Has the onsite emergency response organization (ERO) been reviewed and perhaps modified to incorporate the new severe accident management functions?

2. Has the AMP been integrated into the emergency response arrangements? Has the plant emergency arrangements been reviewed and perhaps modified to include new severe accident management functions and responsibilities?

3. Are criteria and procedures used by the operational staff for classification and activation of the response organization (to include the accident management components) adequate for timely implementation of the accident management functions?

4. Do the emergency arrangements support performance of the accident management functions under emergency conditions to include simulations performance of other response actions, hazardous work conditions, time constraints and stress?

5. Have the accident management actions and assessments that may influence taking protective action on- or off-site (e.g., intentional venting of the containment) been co-ordinated with the on- and off-site response organizations responsible for taking such actions?

6. Has the utilization of off-site emergency services been integrated into the emergency arrangements

7. Have the lines of responsibility been clearly defined for evaluators, decision makers and implementers, for all severe accident management functions?

8. Has the method and responsibility for communications between the different involved parts of the ERO been defined?

9. Are the criteria, responsibilities and required time response for activation of the severe accident management team defined and realisable?

10. Have the required information needs been provided at the appropriate location for the severe accident management team to monitor plant status?

3.3.9. Staffing and qualification

For severe accident management, new functions are being performed by (typically) the Technical Support Staff onsite. It is necessary to ensure that the SAMG user team is appropriately constituted and qualified. Issues related to the capability of the plant and emergency staff to perform accident management functions under accident conditions must be addressed:

1. Has it been shown that the staff can perform their assigned accident management functions under the conditions anticipate during an emergency (stress, time, heat, radiation, live steam, lifting, climbing, etc.)?

2. Has it been shown that there will be sufficient equipped staff available to perform the accident management functions in time during an emergency?

3. Have possible conflicts with other response functions (e.g. search and rescue, security, fire fighting) been considered and resolved?

4. Have provisions been made to effectively utilize the emergency services (e.g. fire fighting) available from off-site to include providing them: prompt access to the site, appropriated training and radiation protection?

5. Has a review of the capabilities of the TSC (or that part of the organization responsible for SAMGs) been performed to ensure that it is appropriately staffed and that staff have the appropriate qualifications?

6. Have the functions inside the emergency arrangements organization been properly described?

7. Has the decision maker and other people involved in the decision process adequate technical knowledge of severe accident phenomena and accident management?

3.3.10. Training needs and training performance

Training of the users of procedures and guidelines, and those who interface with them is a key implementation task:

1. Was a training plan developed, in a timely fashion, which identified which staff (individuals and groups) need training, and at what level? Is a training programme available for each function described in the emergency plans?

2. Does the training provided focus on correct execution of the emergency plan tasks and, hence, involve knowledge based, skill based and efficiency oriented training as described in [6]?

3. Does the training programme consist of an appropriate mix of classroom training, self-study, and exercises/drills?

4. Does the training programme contain topics, which vary depending on the function of the staff being trained?

5. Are drills and exercises conducted under conditions that realistically simulate the conditions present during an emergency to include: simulations performance of other response actions, hazardous work conditions, time constraints and stress?

6. Is there a mechanism for self-assessment of performance during drills and exercises?

7. Is there a mechanism for feeding back lessons learned from exercises, drills and training into the guidance material, or into the training material itself?

8. Have the retraining and refresher requirements been identified in the training plan? Is the chosen frequency of training compatible with the staff-training programme of the plant whilst ensuring that the responsible staff are well-informed?

9. Has appropriate use of simulators been included in the training plan?

3.3.11. AMP revisions

1. Has a mechanism been put in place, which allows for the update of the programme when new or revised information becomes available?

3.4. Review in relation to the basic safety principles

In addition to the detailed review based on a set of questions provided in Section 3.3 above, completeness of the provisions important for successful performing of AMP can be checked by screening, using ‘objective trees’ presented in Figs 2–6. For given objectives of the accident management (i.e. control of severe accident conditions, including prevention of accident progression and mitigation of consequences of severe accidents) a set of challenges to achieve these objectives is identified. These challenges result from one or several constitutive mechanisms. For each of the mechanisms, the list of possible safety provisions, which contribute to prevention of the mechanism to take place, is provided.

The reviewer is expected to compare provisions identified in the objective trees to the capabilities and provisions of a NPP and to evaluate whether the required provisions exist and how they are implemented. Bottom-up method of screening of individual provisions is used. Judgement should be made what is the level of implementation of each particular provision to prevent mechanisms from occurring to achievement of the accident management objectives. If a satisfactory answer on implementation of each provision belonging to the specific mechanism is given, than the relevant mechanism can be considered as prevented to occur.

It has to be mentioned that not all of the provisions shown in the objective trees should be considered as absolutely necessary for completeness of the AMP; in fact, some of the provisions are optional. It is up to the reviewer to judge whether an absence of a provision really leads to the weakness in-defence in-depth or not.

In the present version of the objective trees for accident management, challenges, mechanisms and provisions were combined into five groups:

- provisions for development of strategies (Fig. 2)
- general provisions for performance of equipment in accident management (Fig. 3)
- provisions for performance of personnel in accident management (Fig. 4)
- specific provisions (technical means) for emergency heat removal, protection of containment structure and limitation of radioactive releases (Fig. 5)
- provisions for integration with emergency arrangements and NPP physical protection (Fig. 6).

More detailed explanation regarding development and use of objective trees for inventorying the defence in depth capabilities for all five levels of defence can be found in the IAEA publication [7]. The method is based on the IAEA Safety Standards and on INSAG-12 publication on basic safety principles for NPPs [5].

3.5. Results of the review

The reporting should contain an evaluation of how well the NPP has developed and implemented its AMP. The report also contains description of important issues and recommendations made by the team. The bases for the issues will be identified and referenced to the IAEA Safety Standards and other safety related IAEA publications, along with good international practices.

A special attention should be paid to management of the uncertainties that are related to various parts of the AMP, but in particular to the mitigative actions. First of all, there is a lot of uncertainty involved in many of the severe accident phenomena. The phenomenological uncertainty can be due to insufficient understanding and modelling of the given phenomena and their influence, or due to the inherent character of phenomena to be unpredictable either because of random behaviour or bifurcation points. There are also uncertainties involved in the equipment capability to perform under accident conditions, in the instrumentation availability and readings and in human behaviour. The management of the uncertainties should be reviewed, in particular:

- the uncertainties due to insufficiency of the analysis tools;
- the uncertainties due to bifurcation in the behaviour of the plant;
- the uncertainties due to equipment capability and availability;
- the uncertainties of the available information during the accident; and
- the uncertainties in the human behaviour.

The conclusions and recommendations should be focused on the critical aspects of an AMP. Thus, they should address at least the following:

1. Compliance of the overall AMP approach with the national requirements;
2. Quality and extent of the accident analysis to support the AMP in all levels;
3. Technical correctness of accident management actions, in accordance with up-to date knowledge, proper management of uncertainties at all levels;
4. Consistency of the accident management procedures and guidelines with other operating procedures;
5. Level of verification and validation of the procedures and guidelines;
6. Compliance of the responsibilities of the accident management staff with the plant emergency arrangements;
7. Consistency of the interface between preventive and mitigative actions and procedures, including the entry and exit criteria,
8. Performance of the equipment and instrumentation during the severe accident conditions.

4. PREPARATION AND CONDUCT OF THE REVIEW

4.1. Preparing the review

The review mission is organized based on a request from a Member State through its official contact point. Details of the mission will vary depending on its scope. The scope is specified in the Member State's request and further clarified by the IAEA team leader and in-country counterpart. This also includes specification of the reference material to be provided prior to the mission and during the mission and preparation of the detailed agenda of the mission. The participants in the review mission are the IAEA review team and its in-country counterparts.

Text cont. on page 25.

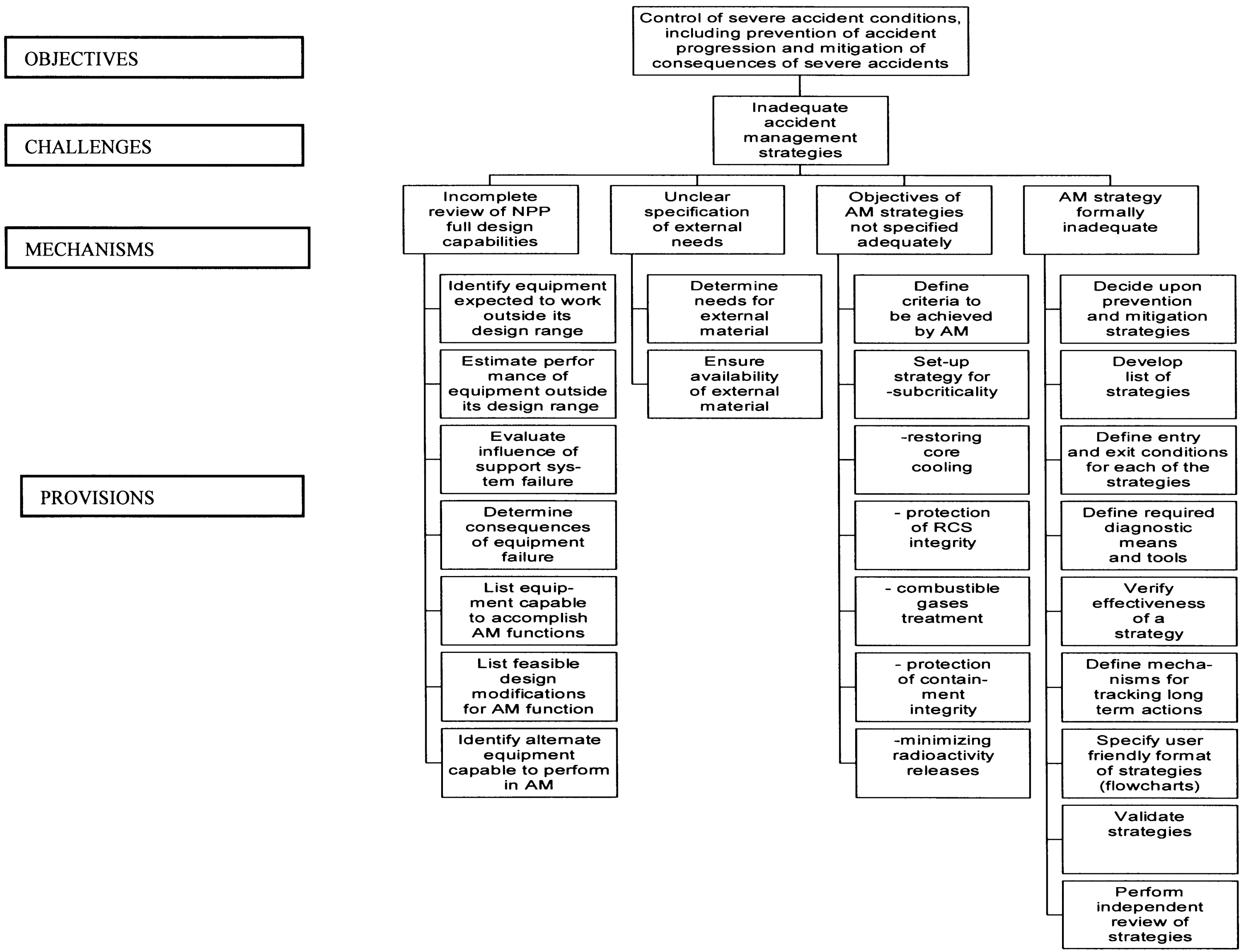

FIG. 2. Provisions for development of strategies for accident management.

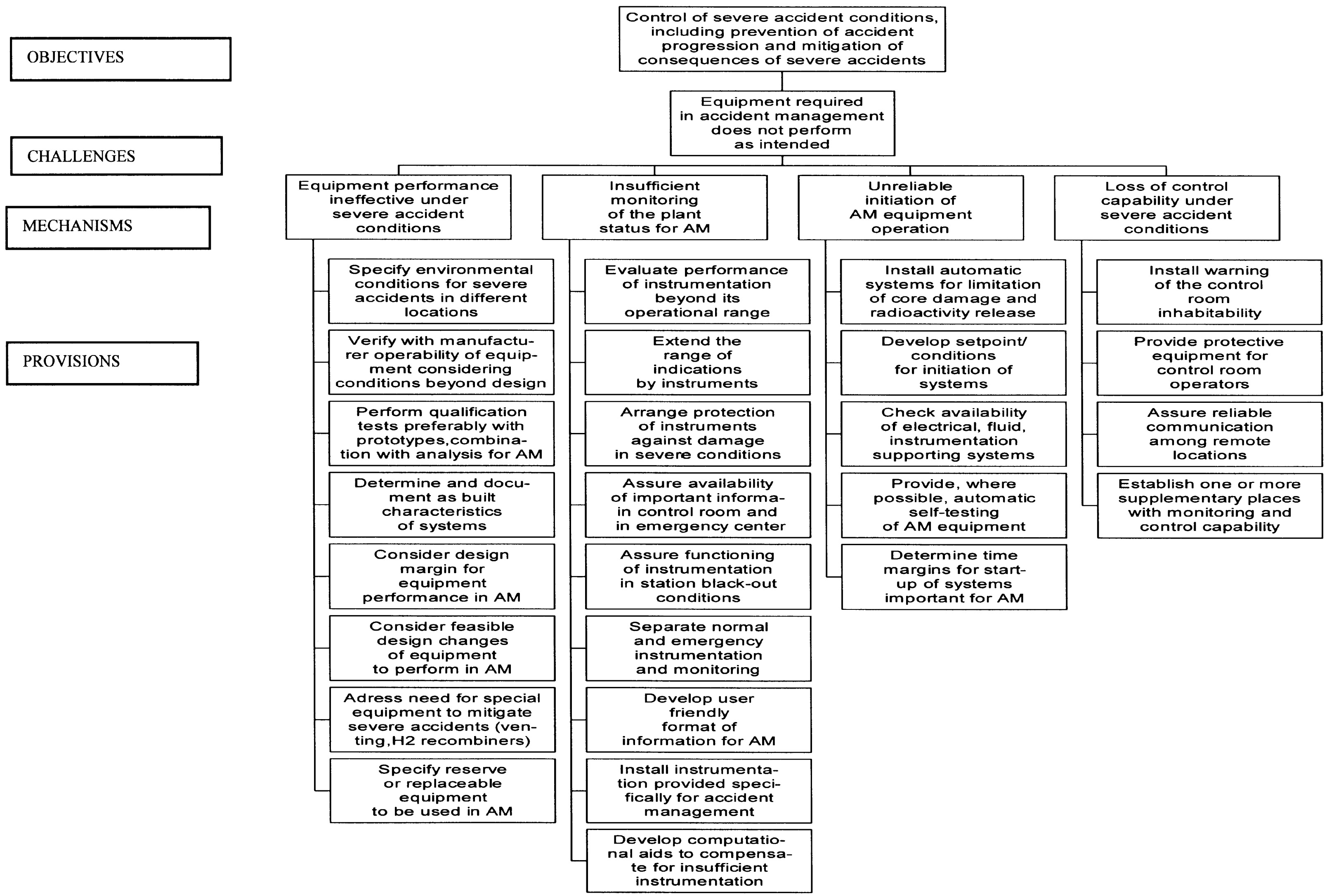

FIG. 3. General provisions for performance of equipment in accident management.

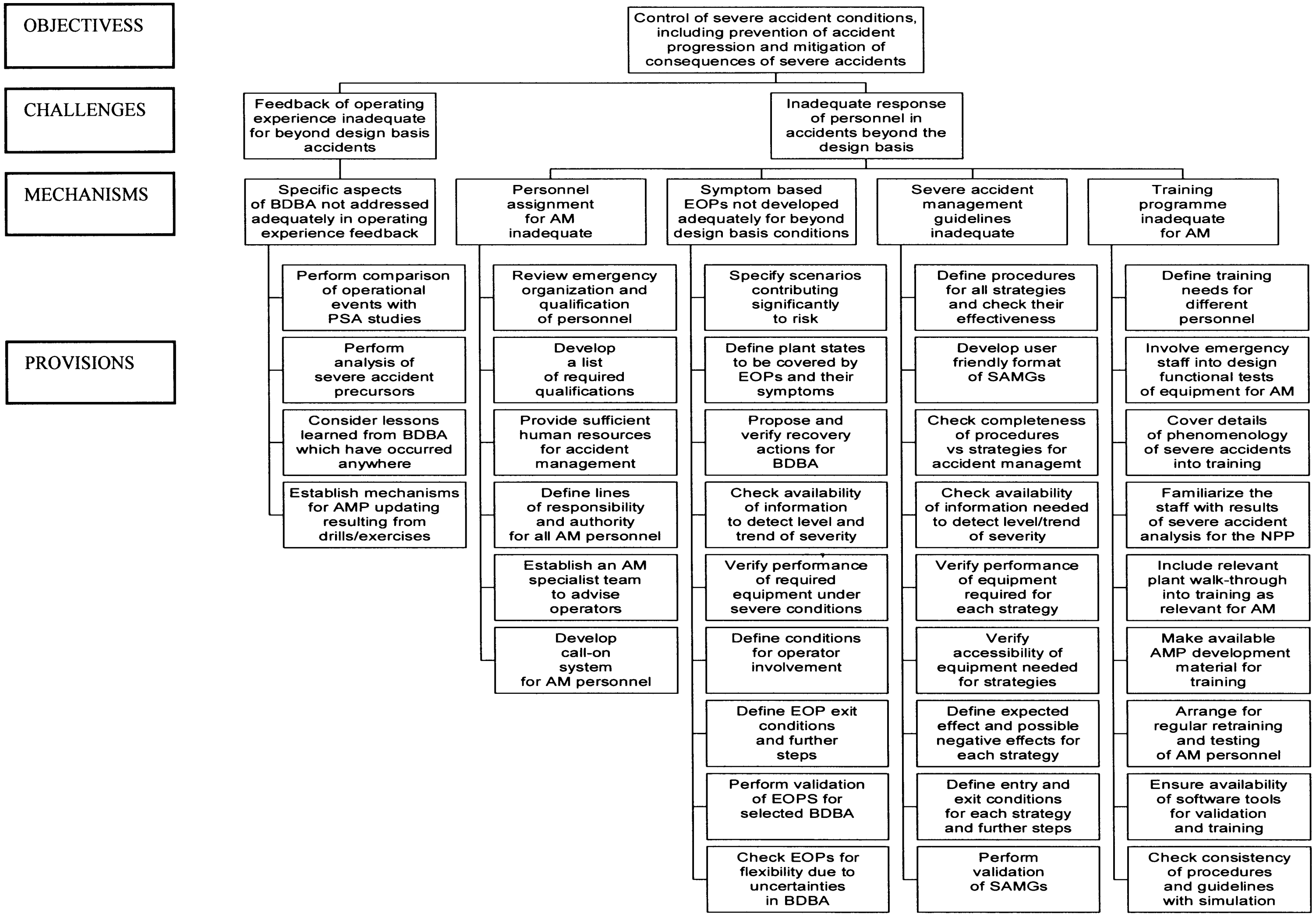

FIG. 4. Provisions for performance of personnel in accident management.

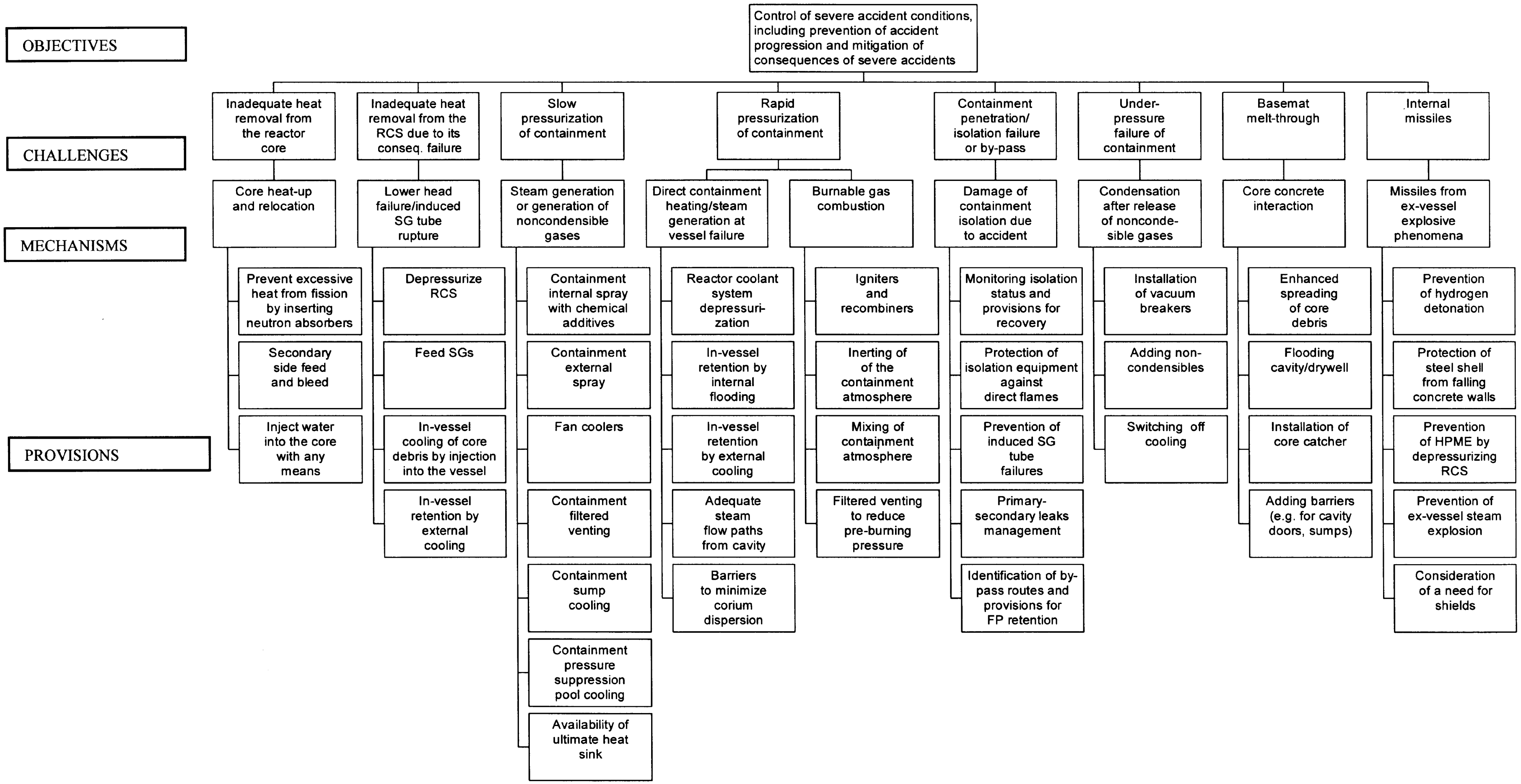

FIG. 5. Provisions for emergency heat removal, protection of containment structure And limitation of radioactive releases.

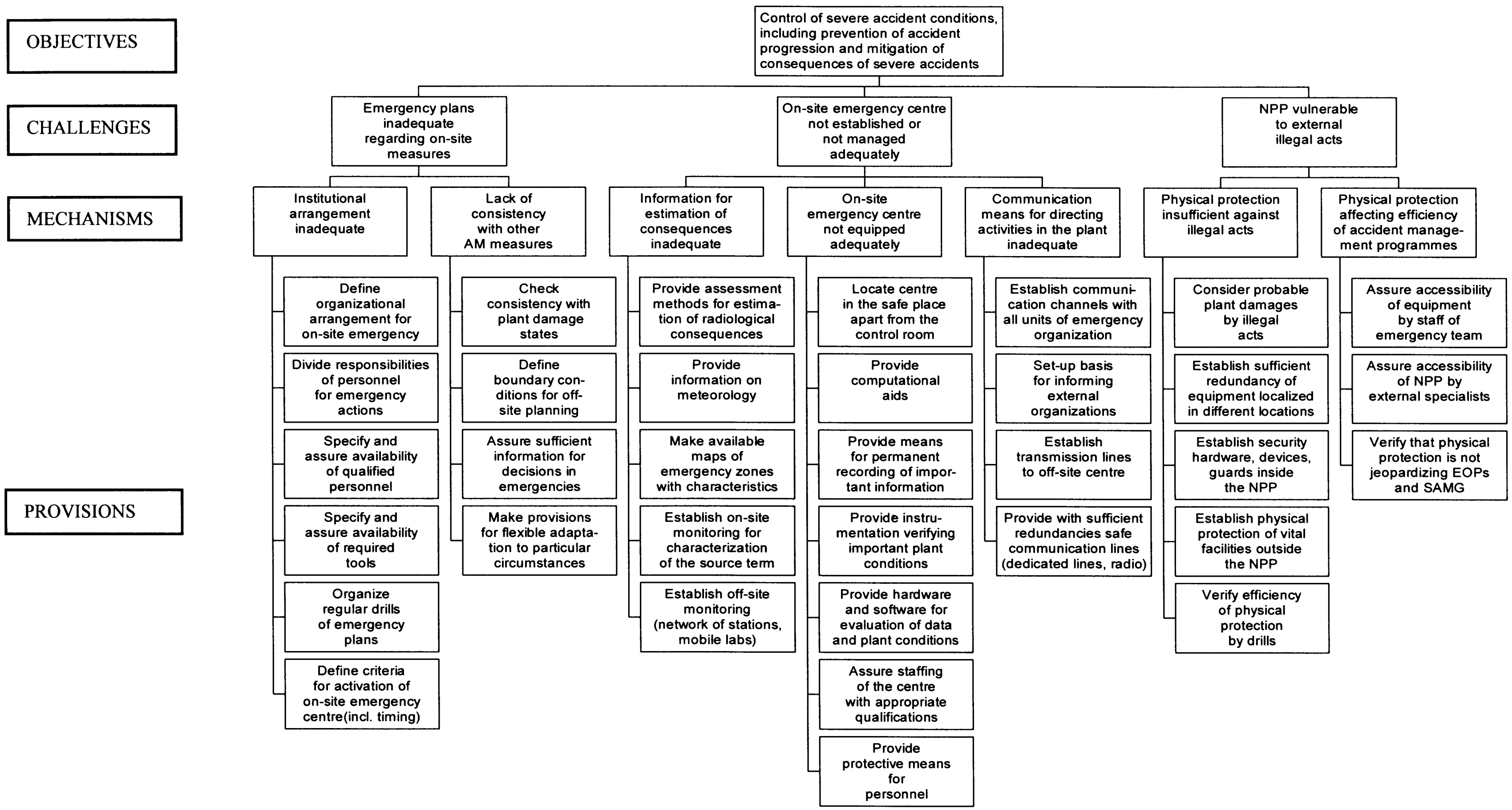

FIG. 6. Provisions for integration with emergency arrangements and npp physical protection.

The IAEA review team is composed of a team leader who is always an IAEA staff member and several (up to four) invited experts. In case of detailed review of accident analysis in support of AMP in parallel with review of the whole Amp, the number of experts can be up to six. The following should be taken into account in selecting the experts:

- the experts should not be selected from the organizations involved in development of AMP to avoid potential conflict of interest;
- team members should overlap in expertise, to have as broad experience in the team as possible;
- variety of views (different approaches) and experience should be represented in the team.

In-country counterparts include representatives of the NPP operating organization and, if required by the operating organization, its consultants and contractors that participated in the work to be reviewed. Representatives of the nuclear regulatory authority may also attend the review.

Responsibilities of the participants in the review mission are as follows:

1. IAEA team leader
    - establishes contacts with the host country and organization;
    - selects the review team members;
    - specifies with the in-country counterpart the scope of the review, reference material to be reviewed prior and during the mission and agenda of the mission;
    - distributes the reference material to the team members prior to the mission;
    - co-ordinates conduct of the mission; and
    - co-ordinates preparation and reviewing of the mission report.

2. IAEA review team members
    - familiarize themselves with the advance reference material;
    - conduct the review of the subject under their responsibility as allocated by the team leader, formulate the issues and corresponding recommendations;
    - write and review the specific sections of the mission report dealing with the subject under their responsibility;
    - review the whole mission report to ensure consistency and good integration between all areas reviewed.

In-country counterparts
- provide the requested advance reference material (at least one month prior to the mission);
- establish the arrangements for the mission (accommodation, transportation, meeting rooms for two working groups working in parallel, access to the facilities, secretarial services); and
- make available necessary documents in the meeting rooms and counterparts for each of the working groups.

4.2. Conducting the review

The review team conducts the review on the basis of the documentation provided, discussion with the in-country counterparts, observations and plant walk-downs as required.

The mission duration is one week which is divided, e.g. into a half a day of general presentations, two days and a half of technical discussions between the IAEA team and the in-country counterparts and of plant walkdowns, one day of report writing and one-half day of the exit meeting. General presentation of the first day should include a short presentation on NPP systems configuration.

For better use of the mission time, it is recommended to establish two working groups (each of them consisting of two experts) and to assign them with specific review areas for detailed technical discussions. Assignment of review areas to the working groups can be as follows; numbering of the review areas is in accordance with section 3.3:

- Working Group 1: Review areas: 1) Definition of overall AMP and its compliance with the national requirements, 2) Quality and extent of the accident analysis to support the AMP, 3) Assessment of plant vulnerabilities, 4) Development of severe accident management strategies, 5) Evaluation of plant equipment and instrumentation.

- Working Group 2: Review areas: 6) Development of accident management procedures and guidelines, 7) Verification and validation of the procedures and guidelines, 8) Integration between AMP and plant emergency arrangements, 9) Staffing and qualification, 10) Training needs and performance, 11) AMP revisions.

There should be a host country coordinator assigned for each of the working groups. The coordinator is not supposed to be capable to answer all the questions raised in the working group, but he should arrange for availability of the competent staff for all necessary explanations.

Team members meet daily to exchange information on their findings and to harmonize their recommendations. Therefore, findings and recommendations of the missions are formulated as consensus opinion of the whole team. If working groups are established, sufficient time should be allocated to mutual review of their products so as to make sure that a consistent and well-formulated document is produced. The detailed evaluation of the review areas is performed using the set of questions (Section 3.3) as a basic guidance for the review. In addition, a complementary 'objective tree' method (Section 3.4) is used to evaluate completeness of the overall AMP and to check the compliance of the AMP with the basic safety principles defined by IAEA Safety Standards and INSAG-12 report.

NPP walk-down may include following:

- Overall NPP walk-down, including localization of equipment important for accident management;
- Operational Support Centre;
- TSC.

Annex 2 provides an example of agenda for a one-week review mission.

4.3. Reporting of the review

4.3.1. Final review report

The review process, findings and conclusions are documented in a final review report, which is prepared as the formal permanent record of the review. Basic structure of the report is shown in Annex 1. The draft mission report is prepared on the site and handed over to the host organization on the last day of the mission.

The final review report is prepared under the review team leader's responsibility. A draft final review report should be submitted to the host organization within one month of the end of the review meeting. The final version of the report is prepared by the team leader, and incorporates comments received on the draft.

4.3.2. Exit meeting

Before leaving the host organization, the review team will hold an exit meeting. The review team will orally convey its observations, preliminary recommendations and suggestions to representatives of the organization, by means of a short presentation by each team member covering his area of review responsibility. The review team should meet before the exit meeting to prepare and agree on the contents of these presentations. The exit meeting attendees from the host organization will be determined by that organization. The exit meeting should be conducted on a free, open and positive atmosphere.

REFERENCES

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[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Preparedness and Response for a Nuclear or Radiological Emergency, Safety Standards Series No. GS-R-2, IAEA, Vienna (2002).

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

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

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Development and Implementation of Accident Management Programmes in Nuclear Power Plants, Safety Reports Series, IAEA, Vienna (in preparation).

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[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Training Material and Technical Support for AMP Courses and Accident Management Staff Training (in preparation).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Safety Glossary, Terminology Used in Nuclear, Radiation, Radioactive Waste and Transport Safety, Version 1.0, IAEA, Vienna (2000).

ANNEX I

BASIC STRUCTURE OF THE FINAL REVIEW REPORT

TC Project RER/9/061
IAEA-TCR-xxxxx
ORIGINAL: English

INTERNATIONAL ATOMIC ENERGY AGENCY

REPORT OF THE

RAMP

(REVIEW OF ACCIDENT MANAGEMENT PROGRAMMES)

MISSION

to the

Krsko

Nuclear Power Plant

SLOVENIA

19–23 November 2001

REVIEW OF ACCIDENT MANAGEMENT PROGRAMMES MISSION
conducted under IAEA Technical Co-operation Project RER/9/061:-
Enhancement of Nuclear Safety Regulatory Authority Effectiveness

DEPARTMENT OF TECHNICAL CO-OPERATION DEPARTMENT OF NUCLEAR SAFETY
Division for Europe, Latin America and West Asia   Division of Nuclear Installation Safety

FRONT PAGE (see above)

CONTENTS

Explanatory text should be introduced for each of the review areas, describing actual situation and comparing with expectations. A comprehensive presentation of all details of the review and of the actual results of the review should be provided. Recommendations should be formulated (if relevant) in a separate paragraph at the end of each of the areas.

ANNEX II

EXAMPLE OF AGENDA FOR ONE WEEK RAMP MISSION

Sunday	
	Arrival of experts, accommodation Team meeting in the place of accommodation
Monday	
09:00- 9:30	Opening of the mission, objectives and organization of the mission
09:30-12:30	Introductory presentations on Accident Management Programme
12:30-13:30	Lunch break
13:30-15:00	General discussion of the AMP Establishment of the Working Groups Discussion on detailed programme of the mission
15:00-16:00	Team meeting at the NPP
16:00-18:00	Individual preparation of experts in hotel, study of documentation, preparation of technical notes
Tuesday	
08:00-11:00	Plant walk-down
11:00-12:30	Interviewing of the NPP staff by the working groups members
12:30-13:30	Lunch break
13:30-15:00	Interviewing of the NPP staff by the working groups members
15:00-16:00	Team meeting at the NPP
16:00-18:00	Individual work of experts in hotel, preparation of technical notes
Wednesday	
08:00-12:30	Interviewing of the NPP staff by the working groups members
12:30-13:30	Lunch break
13:30-15:00	Interviewing of the NPP staff by the working groups members
15:00-16:00	Team meeting at the NPP
16:00-18:00	Individual work of experts in hotel, preparation of technical notes
Thursday	
08:00-12:30	Preparation of the mission report, summary of interviews, formulation of the recommendations by the experts
12:30-13:30	Lunch break
13:30-15:00	Discussion of the recommendations between the experts and NPP staff
15:00-16:00	Team meeting at the NPP
16:00-18:00	Finalization of the recommendations, preparation of the mission report
Friday	
08:00-11:00	Preparation of the mission report
11:00-12:30	Exit meeting

ABBREVIATIONS

AMP	accident management programme
BDBA	beyond design basis accident
DBA	design basis accident
ECCS	emergency core cooling system
EOP	emergency operating procedures
ERO	emergency response organization
FP	fission products
HPI	high pressure injection
INSAG	International Safety Advisory Group
LOCA	loss of coolant accident
LPI	low pressure injection
OSART	operational safety review team
PSA	probabilistic safety assessment
RAAM	review of accident analysis for accident management
RAMP	review of AMPS
SA	severe accident
SAMG	severe accident management guidelines
TSC	technical support centre
QA	quality assurance

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