Canadian Nuclear Safety Commission
Commission canadienne de sûreté nucléaire

REGULATORY
GUIDE

Severe Accident Management Programs for Nuclear Reactors

G–306

May 2006

Canada

TYPES OF REGULATORY DOCUMENTS

Regulatory documents support the Canadian Nuclear Safety Commission (CNSC) regulatory framework. By expanding on expectations set out in general terms in the NSCA and associated regulations, regulatory documents provide one of the core management tools upon which the CNSC relies to fulfill its legislated obligations.

The regulatory documents most commonly published by the CNSC are *regulatory policies*, *regulatory standards*, and *regulatory guides*. At the highest level, regulatory policies provide the direction for regulatory standards and guides, which serve as the policy "instruments." A fourth type of regulatory document, the *regulatory notice*, is issued when warranted. Because the information in a *regulatory notice* must be conveyed with relative urgency, the development process is faster than that applied to the other documents.

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Regulatory Guide (G): The regulatory guide informs licensees about **how** they can meet CNSC expectations and requirements. It provides licensees with a recommended approach for meeting particular aspects of the requirements and expectations associated with their respective licensed activities.

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SEVERE ACCIDENT MANAGEMENT PROGRAMS FOR NUCLEAR REACTORS

1.0 PURPOSE

The purpose of this regulatory guide is to help a person who applies for, or holds, a licence to construct or operate a nuclear reactor to develop and implement a "severe accident management (SAM) program," in accordance with the *Nuclear Safety and Control Act* (NSCA).

2.0 SCOPE

This document describes a typical severe accident management (SAM) program for a nuclear reactor. A person who applies for, or holds, a licence to construct or operate a nuclear reactor should follow this guide when developing and implementing measures to help:

1. Prevent the escalation of a reactor accident into an event involving severe damage to the reactor core;
2. Mitigate the consequences of an accident involving severe damage to the reactor core; and
3. Achieve a safe, stable state of the reactor and plant over the long term.

3.0 RELEVANT LEGISLATION

While the NSCA and its regulations do not contain express references to SAM programs for nuclear reactors, the following provisions of the NSCA and regulations are relevant to this guide:

1. One of the purposes of the NSCA is to provide for the limitation "to a reasonable level and in a manner that is consistent with Canada's international obligations of the risks to national security, the health and safety of persons, and the environment, that are associated with the development, production, and use of nuclear energy;"
2. Paragraph 24 (4) of the NSCA stipulates that "no licence may be issued, renewed, amended, or replaced unless, in the opinion of the Commission, the applicant (a) is qualified to carry on the activity that the licence authorizes the licensee to carry on, and (b), in carrying on that activity, will make adequate provision for the protection of the environment, the health and safety of persons, and the maintenance of national security and measures required to implement international obligations to which Canada has agreed;"

3. Paragraph 12 (1) (*f*) of the *General Nuclear Safety and Control Regulations* requires every licensee to take all reasonable precautions to control the release of radioactive nuclear substances within the site of the licensed activity and into the environment as a result of licensed activity; and
4. Paragraph 6 (*k*) of the *Class I Nuclear Facilities Regulations* stipulates that an application for a licence to operate a Class I nuclear facility shall contain information on the proposed measures to prevent or mitigate the effects of accidental releases of nuclear substances on the environment, and the health and safety of persons.

4.0 OVERVIEW

A SAM program provides an additional defence against the consequences of those accidents that fall beyond the scope of events considered in the reactor design basis. The establishment of a SAM program should ensure that personnel involved in managing an accident have the information, procedures, and resources necessary to carry out effective on-site actions.

To the extent practicable, a SAM program builds on existing emergency operating procedures and emergency preparedness measures. Specific provisions of a SAM program take the reactor design into account, in particular, the reactor power and available protective systems. For reactors of low thermal power, it may be possible to show that certain elements of a SAM program are unnecessary or not applicable. It is the responsibility of a licensee to demonstrate that SAM provisions are adequate to limit the risk posed by severe accidents.

SAM is intended to bring the reactor and the plant in general into a controlled and stable state. Long-term on-site recovery actions, as well as off-site actions, are beyond the scope of a SAM program.

5.0 GOALS AND PRINCIPLES OF SEVERE ACCIDENT MANAGEMENT

The licensee should adhere to the goals and principles outlined in subsections 5.1 and 5.2 when developing a SAM program.

5.1 SAM Goals

The goals of an effective SAM program include:

1. Terminating core degradation early;
2. Achieving a stable and controlled state of the reactor core or core debris;
3. Maintaining containment integrity; and
4. Minimizing the release of radioactive products into the environment.

5.2 SAM Principles

The principles of an effective SAM program include:

1. Ensuring a balance between reliance on organizational measures and design capabilities;
2. Identifying the roles and responsibilities of the operating staff and special emergency teams;
3. Identifying and evaluating plant systems and features suitable for use during severe accident management, including those not originally designed for accident management; and
4. Providing adequate training to the operating staff and special emergency teams.

6.0 CONSIDERATIONS FOR PROGRAM DEVELOPMENT

Results of risk assessment and accident analysis are important considerations for SAM program development.

6.1 Risk Assessment

The results of probabilistic risk assessment should assist the licensee to:

1. Verify that SAM would be effective for the severe accident sequences with the highest probability of occurrence, including natural and human-induced external hazards;
2. Provide a basis for the assessment of safety benefits of potential design enhancement options; and
3. Identify accident scenarios for personnel training and drill purposes.

6.2 Accident Analysis

The results of accident analysis should assist the licensee to:

1. Specify the criteria that would indicate the onset of a severe accident;
2. Identify the symptoms (i.e., parameters and their values) by which plant personnel may determine the reactor core condition and state of protective barriers;
3. Identify the challenges to fission product boundaries in different reactor states, including shutdown states;
4. Evaluate the timing of such challenges in order to improve the potential for successful human intervention;
5. Identify the plant systems and material resources that may be used for SAM purposes;
6. Verify that SAM actions would be effective to counter challenges to protective barriers;

7. Evaluate performance of instrumentation under accident conditions; and
8. Develop and validate computational aids for SAM.

7.0 DEFINING HIGH-LEVEL ACCIDENT RESPONSE

The licensee should define categories of accident response actions and carry out evaluation of systems and equipment, and the assessment of material resources needed to perform those actions.

7.1 Preventive and Mitigating Actions

The licensee should identify practical preventive and mitigation actions to achieve the SAM goals. Generally, accident management actions should include:

1. Establishing and maintaining reactivity control;
2. Ensuring availability of heat sink for heat generated in the reactor core;
3. Depressurizing the primary heat transport system;
4. Maintaining coolant inventory in the primary heat transport system;
5. Controlling pressure and water inventory in steam generators;
6. Ensuring containment isolation;
7. Controlling the containment pressure and temperature;
8. Controlling the concentration of flammable gases; and
9. Controlling radioactive releases.

As appropriate, the licensee should develop guidance documents for operators and emergency teams to implement such actions.

7.2 Evaluation of Systems and Equipment

If systems and equipment are expected to perform in a way or under conditions that were not considered in their original design, then the licensee should conduct an assessment of their potential availability, effectiveness, and limitations for use in support of a SAM program. Existing systems may warrant design enhancement if the assessment reveals that the potential consequences of severe accidents are such that the existing systems may not provide the desired preventive and mitigating capabilities.

7.3 Assessment of Material Resources

The licensee should perform an assessment to determine the availability of coolant, energy, and other material resources that may be required for the effective completion of SAM actions.

8.0 SAM PROCEDURES AND GUIDELINES

The licensee should develop SAM guidelines and procedures that account for factors specific to the plant design. They should also include:

1. The organizational structure of the SAM program within the facility, with identification of the roles and responsibilities of all program participants, including operating staff and emergency response and support groups;
2. The parameters that define the transition from emergency operating procedures to SAM procedures;
3. Key parameters to diagnose the state of various reactor and plant systems throughout the progression of the accident;
4. Actions to be taken to counter challenges to the reactor and plant systems;
5. Indicators that can be used to judge the success of the implemented actions; and
6. The communication protocol to be followed during implementation of SAM.

In developing SAM procedures and guidelines, the licensee should consider that information available to the operating staff or emergency groups may be incomplete and characterized by significant uncertainties.

9.0 OTHER CONSIDERATIONS

An effective SAM program should identify information and training requirements for the operating staff and emergency teams.

9.1 Information Needs

In determining the information needs, the licensee should address the following aspects:

1. The need to diagnose that a severe accident is occurring;
2. The need to determine the state of various plant systems, especially the reactor core, the primary heat transport system, emergency cooling systems, major heat sinks, and containment system;
3. The need to obtain information on key parameters, such as neutron flux, temperatures, pressures, flows, combustible gas concentrations, and radiation levels; and
4. The need to confirm the effectiveness of the SAM actions.

The licensee should also assess the availability and accuracy of instrumentation and information management systems credited in SAM.

Given that, during an accident, the total information flow may be overwhelming, and that some of the indications may be contradictory due to failed equipment, the licensee should consider using diagnostic and support tools to provide assistance in decision making for emergency teams.

9.2 Personnel Training

The licensee should provide operating staff and emergency groups with training commensurate with their respective roles in accident management, enabling them to:

1. Understand their roles and responsibilities within the SAM program;
2. Learn about severe accident phenomena and processes;
3. Become familiar with the activities to be carried out;
4. Enhance their ability to perform in stressful conditions; and
5. Verify the effectiveness and improve the clarity of SAM procedures and guidelines.

Training programs should address the roles to be performed by the different groups, and include drills and exercises to enable assessment of the interactions between the various groups involved in SAM.

To the extent practicable, the licensee should use simulator training, because it provides a realistic and interactive environment and is an efficient method for enhancing human response in complex situations.

9.3 Organizational Responsibilities and Interfaces

Clearly defined roles and responsibilities of involved personnel and organizations are an essential component of an effective SAM program.

9.3.1 Identification of Organizational Groups

The licensee should establish the roles and responsibilities of the following participants:

1. Control room operators;
2. Field personnel;
3. Shift supervisors and shift managers;
4. Station emergency response groups;
5. Station management;
6. Advisory and supporting groups; and
7. Corporate utility emergency centre personnel.

The licensee should also establish qualification, training, deployment, and staffing numbers for the various organizational groups involved in the management of severe accidents.

9.3.2 Communication Interfaces

During a severe accident, no single group will have the complete information, knowledge, and skills required to manage the accident. It is therefore important to establish effective communication interfaces among groups. These interfaces will then allow efficient integration of the information and expertise available within the operating organization or from other involved authorities.

An effective communication interface between the operating organization and the provincial and other appropriate emergency organizations should clearly delineate responsibilities, and specify the scope and timing of the information and the support that the provincial emergency organization and other involved organizations will receive.

10.0 VALIDATION AND REVIEW

The licensee should validate a SAM program, upon its establishment, to confirm its effectiveness, usability, technical accuracy, and scope. This validation should include modelling of selected accident scenarios with and without consideration of accident management actions, as well as drills and exercises.

The licensee should also perform periodic reviews of a SAM program, provisions, guidelines, and procedures to reflect changes in plant design, operational modes, or organizational responsibilities. The reviews should address new information that has been derived from drills, exercises, training programs, safety analyses, experimental research or other sources.

11.0 DOCUMENTATION

The licensee should provide the Canadian Nuclear Safety Commission (CNSC) with the following information about a SAM program:

1. Goals and principles used for development and implementation of the SAM program and provisions;
2. Results of probabilistic, analytical, and design studies conducted in support of SAM;
3. Results of assessments of the efficiency of preventive and mitigating actions;
4. SAM guidelines and procedures;
5. Performance capabilities for the systems and equipment that can be used in support of SAM procedures;
6. Information requirements for effective accident management;
7. Responsibilities of persons and organizations involved in SAM;

8. Requirements for personnel training; and
9. Results of SAM validation and reviews.

GLOSSARY

Accident
Any unintended event, including operating errors, equipment failures or other mishaps, with potentially substantial protection or safety consequences.

CNSC
Canadian Nuclear Safety Commission

Design Basis Accident (DBA)
Accident conditions against which a nuclear power plant is designed, and for which the damage to the fuel and the release of radioactive material are kept within authorized limits.

Mitigation
Measures aimed at limiting the scale of core damage, preventing interaction of the molten material with containment structures, maintaining containment integrity, and minimizing off-site releases.

Prevention
In the context of severe accident management, measures aimed at averting or delaying the onset of severe accident.

Severe Accident
Accident conditions more severe than a design basis accident (DBA) and involving significant core degradation.

Severe Accident Management (SAM) Program
A program that establishes

1. the actions to be taken to prevent severe damage to the reactor core, to mitigate the consequences of the core damage should it occur, and to achieve a safe, stable state of the reactor over the long term; and

2. the preparatory measures necessary for implementation of such actions.