Canadian Nuclear Safety Commission
Commission canadienne de sûreté nucléaire

REGULATORY
STANDARD

Probabilistic Safety Assessment (PSA) for Nuclear Power Plants

S–294

April 2005

Canada

REGULATORY DOCUMENTS

The legal framework within which the Canadian Nuclear Safety Commission (CNSC) operates includes the *Nuclear Safety and Control Act* (NSCA), its Regulations and other legal instruments such as licences, certificates and orders. The legal framework is supported by regulatory documents issued by the CNSC, the main types of which are:

Regulatory Policy (P): a document that describes the philosophy, principles or fundamental factors that underlie the CNSC's approach to its regulatory mission. It provides direction to CNSC staff and information to stakeholders.

Regulatory Standard (S): a document that describes CNSC requirements. It imposes obligations on the regulated party, once it is referenced in a licence or other legally enforceable instrument.

Regulatory Guide (G): a document that indicates acceptable ways of meeting CNSC requirements, as expressed in the act, Regulations, regulatory standard or other legally-enforceable instrument. It provides guidance to licensees and other stakeholders.

Regulatory Notice (N): a document that provides licensees and other stakeholders with information about significant matters that warrant timely action.

REGULATORY STANDARD

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The document can be viewed on the CNSC Internet website at (www.nuclearsafety.gc.ca). Copies may be ordered in English or French using the contact information below:

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TABLE OF CONTENTS

PROBABILISTIC SAFETY ASSESSMENT (PSA) FOR NUCLEAR POWER PLANTS

1.0 PURPOSE

The purpose of this Regulatory Standard, when incorporated into a licence to construct or operate a nuclear power plant (NPP) or other legally enforceable instrument, is to assure that the licensee conducts a "probabilistic safety assessment (PSA)" in accordance with defined requirements.

2.0 SCOPE

This Regulatory Standard sets out the requirements for the PSA that a licensee who constructs or operates a NPP shall conduct, when required by the applicable licence or other legally enforceable instrument.

3.0 RELEVANT LEGISLATION

The *Nuclear Safety Control Act* (NSCA, the act) and its regulations do not contain explicit references to PSA for NPPs. However, the following provisions are relevant to this Standard:

1. section 3 of the NSCA which sets out the purpose of the act, provides 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. subsection 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) will, in carrying on that activity, 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"; and
3. subsection 24(5) of the NSCA stipulates that a licence that is issued by the Commission may contain any term or condition that the Commission considers necessary for the purposes of this act.

4.0 BACKGROUND

The following International Atomic Energy Agency (IAEA) Safety Series documents provide general guidance for conducting quality PSAs:

1. IAEA Safety Series No. 50-P-4, *Procedures for Conducting Probabilistic Safety Assessments of Nuclear Power Plants (Level 1)*; and
2. IAEA Safety Series No. 50-P-8, *Procedures for Conducting Probabilistic Safety Assessments of Nuclear Power Plants (Level 2), Accident Progression, Containment Analysis and Estimation of Accident Source Terms*.

5.0 PSA REQUIREMENTS

The licensee shall carry out the following activities:

1. Perform a facility specific Level 2 PSA for each NPP in question;
2. Establish and apply a formal quality assurance process for conducting a PSA, such as the Canadian Standards Association (CSA) Standard N286.2, *Design Quality Assurance for Nuclear Power Plants*;
3. Ensure that the PSA models reflect the plant as built and operated, as closely as reasonably achievable within the limitations of PSA technology and consistent with risk impact;
4. Update the PSA models every three years or sooner if major changes occur in the facility;
5. Ensure that the PSA models are developed using assumptions and data that are realistic and practical;
6. Ensure that the level of detail of the PSA is consistent with the NPP testing and configuration management programs;
7. Seek CNSC acceptance of the methodology and computer codes to be used for the PSA;
8. Include both internal and external events[1] in the PSA;
9. Include both at power and shutdown states in the PSA; and
10. Include sensitivity analysis, uncertainty analysis and importance measures in the PSA.

[1] For external events, the licensee may, with the agreement of "persons authorized" by the Commission, choose an alternative analysis method to conduct the assessment. In such cases, the external event may be excluded from the PSA.

GLOSSARY

At power
A plant state characterized by the following conditions:

1. The reactor being critical at 100% power;

2. Automatic actuation of safety systems not blocked; and

3. Essential support systems aligned in their normal power configuration.

Configuration management
The process of identifying and documenting the characteristics of a facility's structures, systems and components (including computer systems and software), and of ensuring that changes to these characteristics are properly developed, assessed, approved, issued, implemented, verified, recorded and incorporated into the facility documentation.

External event
Any event that proceeds from the environment and can cause a plant's System, Structures and Components (SSC) to fail. External events include, but are not limited to, earthquakes, floods and hurricanes.

Importance measures
Indices that indicate the importance of an event or group of events. These comprise the following three importance measures:

1. Fussel-Vesely Importance: For a specific basic event, the fractional contribution to PSA results for all accident sequences containing that basic event;

2. Risk Increase Ratio (RIR), also referred to as Risk Achievement Worth (RAW): indicates the factor by which the PSA results would increase if the basic event is assumed to happen with certainty (failure probability = 1.0); and

3. Risk Decrease Ratio (RDR), also referred to as Risk Reduction Worth (RRW): indicates the amount of reduction in the PSA results to be gained if the basic event is assumed to be available (failure probability = 0.0).

Internal event
Any event that proceeds from a human error or SSC failure.

Nuclear power plant (NPP)
Any nuclear fission reactor installation that has been constructed to generate electricity on a commercial scale and is a Class IA nuclear facility, as defined in the *Class I Nuclear Facilities Regulations*.

Probabilistic Safety Assessment (PSA)
For a NPP or nuclear fission reactor, a comprehensive and integrated assessment of the safety of the plant or reactor. The safety assessment considers the probability, progression and consequences of equipment failures or transient conditions to derive numerical estimates that provide a consistent measure of the safety of the plant or reactor, as follows:

1. A Level 1 PSA identifies and quantifies the sequences of events that may lead to the loss of core structural integrity and massive fuel failures;

2. A Level 2 PSA starts from the Level 1 results, and analyses the containment behaviour, evaluates the radionuclides released from the failed fuel and quantifies the releases to the environment; and

3. A Level 3 PSA starts from the Level 2 results, and analyses the distribution of radionuclides in the environment and evaluates the resulting effect on public health.

A PSA may also be referred to as a Probabilistic Risk Assessment (PRA).

Sensitivity analysis
The process of assessing the impact on the PSA results from a variation in the probability of an event or a modeling assumption.

Shutdown
A plant state characterized by the reactor being in a guaranteed shutdown state. Automatic actuation of safety systems could be blocked and support systems in abnormal configuration.

Uncertainty analysis
The process of identifying and characterizing the sources of uncertainty in the analysis, evaluating their impact on the PSA results, and developing, to the extent practical, a quantitative measure of this impact.

REFERENCES

1. IAEA. *Procedures for Conducting Probabilistic Safety Assessments of Nuclear Power Plants (Level 1)*. Vienna, 1992. Safety Series No. 50-P-4. ISBN 92-0-102392-8.

2. IAEA. *Procedures for Conducting Probabilistic Safety Assessments of Nuclear Power Plants (Level 2), Accident Progression, Containment Analysis and Estimation of Accident Source Terms*. Vienna, 1995. Safety Series No. 50-P-8. ISBN 92-0-102195-X, ISSN 0074-1892.

3. Canadian Standards Association (CSA). *Design Quality Assurance for Nuclear Power Plants*. CAN/CSA-N286.2.