The Risk Handbook – A Web-Based Application to Support Regulatory Site Inspections of Nuclear Power Plants in Canada

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ABSTRACT:

The Risk Handbook is an internal project initiated by the Probabilistic Safety Assessment and Reliability Division at the Canadian Nuclear Safety Commission (CNSC) to support the organization's modern, risk-informed and performance-based regulatory approach. The Risk Handbook summarizes the probabilistic safety assessment (PSA) results and insights, and information concerning the performance of systems important to safety for each Canadian nuclear power plant (NPP) in support of the CNSC's regulatory compliance verification program. The project has two main objectives: first, to provide introductory PSA training to CNSC site inspectors, and second, to develop a user-friendly, web-based tool to summarize PSA results and insights in order to help CNSC staff optimize inspection planning and evaluate results. The overall intent of the Risk Handbook is to complement existing CNSC inspection manuals and procedures, while encouraging CNSC staff to consider PSA results and insights as an additional input for the conduct of regulatory activities, primarily focusing on applications for inspections.

This paper will provide a brief background on the CNSC's PSA and reliability requirements for NPP licensees and on the CNSC's risk-informed approach. It will then discuss the Risk Handbook's purpose, development and structure, lessons learned, perspectives for future improvements and general conclusions.

Keywords: Inspections, PSA, Reliability, Risk-Informed

1. CANADIAN PROBABILISTIC SAFETY ASSESSMENT AND RELIABILITY REGULATORY REQUIREMENTS

The Canadian Nuclear Safety Commission (CNSC) requires nuclear power plant (NPP) licensees to have Probabilistic Safety Assessment (PSA) and reliability programs. The CNSC has published two regulatory documents, REGDOC-2.4.2, *Probabilistic Safety Assessment (PSA) for Nuclear Power Plants* [1], and REGDOC-2.6.1, *Reliability Programs for Nuclear Power Plants* [2], which have been incorporated into each NPP's Licence Conditions Handbook.

REGDOC-2.4.2 [1] was published in May 2014. It supersedes Regulatory Standard S-294 [3], and includes amendments to address findings from the Fukushima Task Force. This document sets high-level requirements for the development of a level 1 and level 2 PSA. The PSA scope must consider internal and external events during at-power, shutdown, and other plant operating states. Amendments to reflect new regulatory requirements include the consideration of other radioactive sources such as irradiated fuel bay and used fuel dry storage, multi-unit impacts, external events and their potential combinations, and the public disclosure of a PSA summary report. Each licensee is required to submit a full-scope PSA update every five years.

REGDOC-2.6.1 was published in August 2017 and supersedes RD/GD-98, *Reliability Programs for Nuclear Power Plants* [4]. This regulatory document contains high-level requirements for the development of a reliability program based on a list of systems important to safety (SIS). The preliminary

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SIS list should be based on PSA importance measures (Risk Achievement Worth (RAW) and Fussell-Vesely (FV)) for Structures Systems and Components (SSCs) from a full-scope PSA. The final SIS list should consider integrated inputs from defence-in-depth, results of deterministic safety analysis, operating experience and expert judgment. Each year, licensees must submit an Annual Risk and Reliability (ARR) report to the CNSC to summarize the predicted unavailability and actual availability (based on system performance) of each SIS.

2. CNSC RISK-INFORMED REGULATORY APPROACH

The CNSC has experience in using the Risk Informed Decision Making (RIDM) approach to support its strategic objective for modern nuclear regulation. According to the organization's departmental plan, "The CNSC uses science-based, risk-informed and technically sound regulatory practices that take into account scientific uncertainties and evolving expectations" [5]. To support this strategic objective, the CNSC has an internal RIDM policy, which is applied when making decisions for developing regulatory requirements and guidance, and when engaging in licensing and compliance activities [6]. For compliance activities, this could include the consideration of PSA importance measures as an additional input for inspection planning.

The RIDM process facilitates a transparent approach to safety and has many applications, including evaluation of design options, optimization of inspection planning, periodic safety reviews, evaluation of operational events, and evaluation of novel issues [8]. RIDM emphasizes that PSA results should be used to complement the traditional deterministic approach, along with consideration of current regulations and standards, consistency with the defence-in-depth philosophy, maintaining a sufficient safety margin, and whether the decision results in a reduction or increase in risk [6]. When PSA is used as an input to RIDM, PSA limitations such as the degree of uncertainty should be considered.

The CNSC has also been involved in the development of Canadian Standards Association (CSA) Standard N290.19:18, *Risk-informed decision making for nuclear power plants*, a new standard issued in 2018, with the overall objective of defining a systematic approach to using RIDM for NPPs. The standard's target audience is designers, operators, and organizations of nuclear regulators and utilities. This standard emphasizes a balanced use of deterministic and probabilistic information in decision making.

3. PURPOSE OF THE RISK HANDBOOK PROJECT

The CNSC's Probabilistic Safety Assessment and Reliability Division (PSARD) initiated the Risk Handbook project as part of the risk-informed, performance based approach to support the regulatory compliance verification program.

The first objective of the project was to provide introductory PSA training to CNSC site inspectors. The training consisted of two parts: first, introductory training on PSA, and second, training on NPP-specific PSA results. The training provided to operations staff aimed to explain the general PSA approach and results (both qualitative and quantitative), as well as the basis behind PSA risk importance measures, and how they can be considered in their compliance activities.

The second objective of this project was to summarize licensees' PSA results and important risk insights in a user-friendly, web-based application that could be used by CNSC site inspectors and regulatory program staff. Each licensee submits a detailed, full-scope PSA every five years, totaling approximately 100,000 pages. It is not a straightforward task for CNSC site inspectors, simply by consulting the submitted PSA reports, to determine and extract what risk insights to use to support their compliance work owing to the extensive level of detail. Therefore, PSARD decided to summarize the key insights that

would be useful in supporting operational compliance activities from the full-scope PSA submissions. Some examples of information included in the Risk Handbook tool include the identification and ranking of SSCs, initiating events, human interactions, and common cause failures from various PSA elements based on the PSA risk importance measures (RAW and FV). RAW is defined as the factor by which severe Core Damage Frequency (SCDF) would increase if the SSC were to fail, whereas FV is the fractional decrease in SCDF if the SSC were successfully operational [9]. These are deemed useful risk metrics for CNSC staff to help them understand the impact of each SSC on overall risk.

The intent of the Risk Handbook is to complement existing CNSC inspection manuals and procedures, while encouraging CNSC staff to consider using risk insights for the conduct of regulatory activities, primarily focusing on how they can be applied to inspections. However, inspection planning must still consider traditional safety analysis reports, procedures and manuals (i.e. Operating Policies and Principles, Safe Operating Envelope, Design Manuals).

The use of the Risk Handbook encourages CNSC staff to consider risk insights and SIS performance to support the compliance verification program. For example, CNSC inspectors may consider SIS with known degradations, more reportable operational events, long hours of maintenance for out-of-service components, long-term impairments resulting in loss of redundancy, a trending of component failures, or an increase in missed or deferred surveillance tests and preventative maintenance. CNSC inspectors may also consider PSA results such as dominant contributors by using component-level importance measures as an input to assess the risk significance of a component when out of service for a prolonged period of time.

In summary, the main purpose of the Risk Handbook project was to create an on-line and user-friendly tool that summarizes PSA results and insights. This facilitates more efficient use of risk insights to support the regulatory compliance program. Relevant references from training materials developed by the International Atomic Energy Agency (IAEA) [10] [11], American Society of Mechanical Engineers (ASME) [12] and PSARD developed training material are provided as supplemental information in each Risk Handbook. Therefore, the Risk Handbook is an internal repository of information that summarizes PSA results and SIS performance, and that includes relevant reference materials for CNSC staff.

4. RISK HANDBOOK CONTENTS AND OVERALL STRUCTURE

The Risk Handbook contains a summary of information extracted from each licensee's levels 1 and 2 PSA reports for the following topics:

1. Levels 1 and 2 – internal events at power
2. Level 1 – internal events at outage
3. Internal fires
4. Internal floods
5. Seismic events
6. High winds

For the level 1 PSA, risk importance measures for systems, components, human interactions, and initiating events were provided. Importance measures provided in the licensee's PSA reports were only those deemed to be risk significant, meaning that the thresholds for RAW and FV were exceeded. However, in response to a request from CNSC inspectors and operations staff, a complete list of PSA importance measures for SSCs was derived from the licensee's level 1 internal events PSA models. CNSC inspectors requested this information so that they could search the risk metrics based on an extensive list of SSCs when planning their inspections. Additional insights for some internal hazard PSAs included the following: internal fires – ignition sources, fire zones and dominant fire scenarios; internal floods – flood sources and flood scenarios; and seismic events – safe shutdown equipment list and

seismic fragility of important SSCs. For level 2 PSA results and insights regarding important scenarios for severe accidents, containment fragility, source terms and release categories were also included.

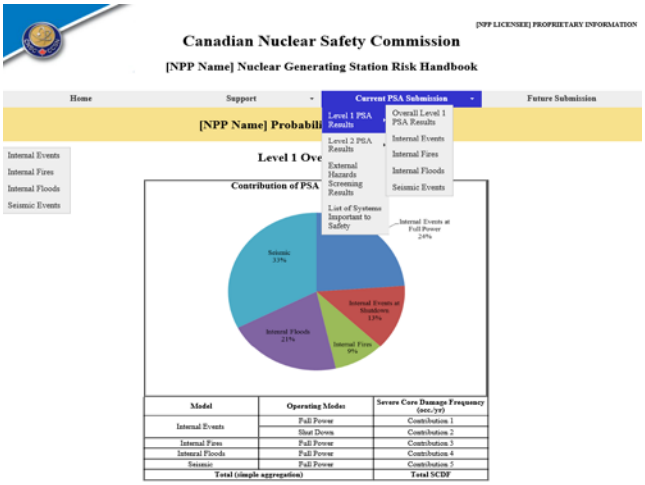
The Risk Handbook also included a summary of the screening results for internal and external hazards. A summary of each hazard and the rationale for screening based on qualitative and quantitative screening criteria was provided.

In addition, the list of SIS was provided in the Risk Handbook to show which systems were included in the reliability program, along with their respective reliability targets.

A guidance section was developed by PSARD to provide information on use of the Risk Handbook for regulatory activities, CNSC regulatory requirements on PSA, the regulatory use of PSA, industry best practices on PSA and its applications, and other references, such as from the IAEA [10] [11] and ASME [12]. The information in the guidance section supplements the training provided to the CNSC's PSA and reliability subject-matter experts.

When the project was initiated in 2015, it was decided that the Risk Handbooks would be developed using Microsoft Word. However, feedback from the pilot training of CNSC site inspectors and regulatory program staff revealed that a more user-friendly application was needed to capture this information. PSARD decided that a web-based application would serve this purpose. The second version of the Risk Handbook was developed using Adobe Dreamweaver CS6 and Microsoft Excel. Information was summarized from the licensee's PSA reports and entered directly into Microsoft Excel. Dreamweaver was used to develop the webpage format. The purpose of using a web-based application was to create a user-friendly interface for site inspectors and regulatory operations staff, and Dreamweaver was identified as a mainstream webpage design tool that was easy and simple to use. It was decided that using a separate database and webpage to make future content updates to the Risk Handbook would be a straightforward way of ensuring that the majority of content changes in the database could be done just by editing the Excel workbook. Figure 1 shows a sample generic page from a Risk Handbook.

Figure 1: Generic example of the overall level 1 PSA results page from the Risk Handbook



5. TRAINING FOR CNSC SITE INSPECTORS AND REGULATORY PROGRAM STAFF

The main objective of the training was to provide CNSC inspectors and operations staff with an introduction to PSA, with an emphasis on the potential applications for inspection planning and other compliance activities. The training was provided over a two-day period by PSA and reliability subject-matter experts from the CNSC. Detailed information on the topics covered is provided below.

Day 1: General PSA training was split into three modules:

- Module 1: General introduction – overview of the fundamental terminology for PSA and reliability, PSA requirements, PSA uses and publications, historical context of the use of PSA in Canada, and safety goals for existing and new reactors.
- Module 2: Level 1 PSA approach – high-level overview of internal and external hazard identification, and the main inputs necessary for the development of a level 1 PSA (examples included initiating event analysis, event tree analysis and fault tree analysis).
- Module 3: Level 2 PSA approach – high-level overview of the development of the level 2 PSA, including an introduction to containment challenges, major tasks necessary for the development of a level 2 PSA, and severe accident progression.

Day 2: NPP-specific PSA results and insights training was split into two modules:

- Module 1: Overview of NPP-specific results for levels 1 and 2 PSA –included SCDF and Large Release Frequency (LRF) results compared against safety goals with relative contributions from internal events and internal hazards.
- Module 2: Use of risk results and insights to support inspection planning – overview of how PSA can be considered an input for inspection planning, PSA importance measures, and examples using a live demonstration of the Risk Handbook tool.

Training was completed for CNSC site inspectors and regulatory program staff responsible for each NPP. Overall, positive feedback was received during the training and was incorporated into future revisions of the Risk Handbook.

6. CHALLENGES AND LESSSONS LEARNED

Firstly, consistency in the level of detail of the Risk Handbooks for each NPP varied owing to differences in the licensees' methodologies and the information provided in the submissions. For example, one major difference was that some licensees developed integrated models, which consisted of inputs from internal events, internal fires, internal floods, and seismic events to calculate and integrate SCDF and LRF. When using the integrated models to determine PSA importance measures for SSCs, the list of SSCs was dominated by the dominant hazard contributor to SCDF or LRF respectively. Secondly, implementation of the Risk Handbook project took longer than anticipated. CNSC staff decided to roll out the Risk Handbooks using a phased approach and to incorporate the feedback from CNSC site inspectors and operations staff following the training sessions. Although this was beneficial for future training sessions, it often delayed the implementation of subsequent Risk Handbook training for other NPP stations. Lastly, it was challenging to ensure that the Risk Handbooks contained the most up-to-date information from the full-scope PSA submissions.

7. PERSPECTIVES FOR FUTURE DEVELOPMENT

For future development of the Risk Handbook, some additional webpage functionalities may be considered, including the potential for a search function and some additional graphics. However, the main consideration for CNSC staff now that training has been completed is the potential development of a formal internal guidance document on how the information from the Risk Handbook PSA results and insights can be used to support CNSC's compliance and verification program. This guidance document

could complement the CNSC's existing internal policy on RIDM. The training provided to CNSC staff was high level, aiming to introduce the PSA in a way that would help staff interpret the information provided in the Risk Handbook. Future refresher training sessions may be provided on an as-needed basis. PSA and reliability specialists at the CNSC will continue to be available to support CNSC operations staff.

8. CONCLUSIONS

PSARD has successfully completed the Risk Handbooks for all NPPs to support the regulatory compliance and verification program at the CNSC. This project was initiated to support the CNSC's risk-informed, performance-based approach by summarizing NPP licensees' results and insights from full-scope PSAs and the ARR reports on SIS. This project was designed to facilitate the use of PSA results and risk insights, alongside SIS performance, to support CNSC site inspectors and regulatory program staff predominantly in inspection planning and evaluation of results. PSARD will continue to incorporate feedback from internal training sessions and update the Risk Handbooks as new information is received from the licensees.

9. REFERENCES

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