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Phase 2 Executive Summary: Pre-Project Review of AECL's Advanced CANDU Reactor — ACR-1000⁻¹

Executive Summary

A vendor pre-project design review of a new nuclear power plant provides an opportunity for the CNSC staff to assess a design prior to any licensing activities, and to identify potential issues that would require resolution. Phase 1 of a pre-project review determines whether the design intent is compliant with CNSC requirements and expectations. Phase 2 goes into further detail to examine if there are any potential fundamental barriers to licensing. CNSC completed a Phase 1 review of AECL's ACR-1000 design in December 2008 which concluded that, at an overall level, the design intent is compliant with the CNSC's regulatory requirements and expectations. A Phase 2 review of the ACR-1000 has now been completed that provides a further level of assurance that AECL has taken into account regulatory requirements and expectations. Based on the Phase 2 review, CNSC staff concludes that there are no fundamental barriers to licensing the ACR-1000 design in Canada. It should be noted that this is subject to the successful completion of AECL's planned activities, in particular those related to research and development.

1.0 Background

1.1 Introduction

The Canadian Nuclear Safety Commission (CNSC) is Canada's sole nuclear regulatory agency operating under the Nuclear Safety and Control Act (NSCA). The CNSC regulates the use of nuclear energy and materials to protect the health, safety and security of Canadians and the environment, and to respect Canada's international commitments on the peaceful use of nuclear energy.

The CNSC conducts vendor pre-project design reviews which assess a nuclear power plant design based on a vendor's proposed reactor technology. A design review is solely intended to provide early feedback on the acceptability of select aspects of a nuclear power plant design based on Canadian regulatory requirements and expectations. The CNSC undertakes a more detailed review of a design and safety case when it considers an application for a licence to construct a nuclear power plant at a specific site.

A design review is an optional service provided by the CNSC when requested by a vendor. This service does not certify a reactor design or involve the issuance of a licence under the NSCA and it is not required as part of the licensing process for a new nuclear power plant. The conclusions of any design review will not bind or otherwise influence decisions made by the Commission.

Atomic Energy of Canada Limited (AECL), a vendor of nuclear power plants, is designing a two-unit Advanced CANDU Reactor (ACR-1000) nuclear power plant, each unit with a gross electrical output of 1165 Megawatts electrical. The ACR-1000 design is largely based on the design concepts and the reactor and

process system designs of current CANDU plants, although there are some important differences between the ACR-1000 design and existing CANDU technologies.

In April 2008, AECL requested the CNSC to perform a pre-project design review of the ACR-1000. Subsequently a Memorandum of Understanding (MOU) was signed between the two organizations. The MOU outlines the agreement on the pre-project design review including the objectives, the technical scope of review, the timetable, deliverables, the costs, working arrangements and general conditions.

1.2 Design Review Objectives

As with other design reviews conducted by the CNSC, the objectives of this review were to:

- Assess whether the ACR-1000 design as submitted was, at an overall level, compliant with the CNSC regulatory requirements;
- Assess whether the design provisions provided for selected review focus areas met the CNSC's expectations for new nuclear power plants in Canada; and
- Identify, based on the review of the focus areas, whether there were any potential fundamental barriers to licensing the ACR-1000 design in Canada.

A vendor pre-project design review provides an opportunity for the CNSC staff to assess the design prior to any licensing activities, and to identify potential issues for resolution relating to the compliance of a design with regulatory requirements and expectations. Such a review will help increase regulatory certainty and ultimately contribute to public safety.

1.3 Design Review Phases

The pre-project review process was divided into two phases:

- **Phase 1: Assessment of Compliance with Regulatory Requirements.** This phase was an overall assessment of the information submitted for 16 review focus areas. Its purpose was to determine whether the design intent in these areas is compliant with the CNSC requirements and meets the CNSC's expectations for the design of new nuclear power plants in Canada. The Phase 1 review of the ACR-1000 design was completed in December 2008, and the CNSC Phase 1 report provided to AECL concluded that, at an overall level, the design intent was compliant with the CNSC's requirements and expectations.
- **Phase 2: Identification of Fundamental Barriers to Licensing.** Subsequent to Phase 1, this phase went into further detail in each of the focus areas with the intent of identifying whether there are any potential fundamental barriers to licensing the design in Canada.

1.4 Definition of Fundamental Barriers to Licensing

CNSC staff considers a fundamental barrier to licensing a new reactor design as a shortcoming in the design or the design process that, if not corrected, could have the potential for significant risk to the public or to workers. The barrier is considered fundamental when there is no clear and adequate path to resolution of a significant

safety issue. The barrier would also be considered to be fundamental if there were significant uncertainties associated with the proposed plan or if the timeline were such that it could be unresolved at the time of an application for a licence to construct.

Given this definition, CNSC staff considers the following as barriers to licensing a nuclear power plant design in Canada:

- Non-compliance with Canadian legal requirements;
- Unjustified non-conformance with Canadian regulatory expectations including those in the regulatory document “Design of New Nuclear Power Plants” (RD-337) or other applicable regulatory documents and national standards for design and analysis;
- Unjustified non-compliance with design and safety analysis Quality Assurance (QA) standards and procedures;
- A design that does not address known issues of safety significance, i.e., the design has not taken into account resolution of safety concerns from past regulatory reviews;
- A design that does not meet the ALARA (As Low As Reasonably Achievable) principle for radiation protection;
- Unproven engineering practices for new or innovative design features; and
- A design for which operational compliance introduces unacceptable operational complexity.

2.0 Phase 2 Design Review: Identification of Fundamental Barriers

2.1 Phase 2 Review Process and Focus Areas

To facilitate the Phase 2 review, AECL submitted documentation including the ACR-1000 Technical Description, ACR-1000 Generic Safety Case Report, and the Safety Design Guides used by the designer and information on the research and development (R&D) being undertaken. Additional information was submitted as requested by CNSC staff in support of the review. In performing the Phase 2 review, CNSC staff aimed to identify: items requiring further information, items requiring further follow-up, issues for which there was clear non-conformance with regulatory expectations, or issues that could lead to potential fundamental barriers.

For the Phase 2 review, CNSC staff retained the same 16 review focus areas as for Phase 1, and added one supplementary focus area – the ACR-1000 R&D program:

- Defense in depth, classification of systems, structures and components (SSCs), dose acceptance criteria
- Fuel design
- Reactor control system
- Reactor core nuclear design
- Means of shutdown
- Emergency core cooling system and emergency feedwater system

- Containment
- Severe accident prevention and mitigation
- Fire protection
- Quality assurance program
- Out-of-core criticality
- R&D program
- Pressure-boundary design provisions for the primary heat transport system
- Radiation protection
- Human factors
- Robustness, safeguards, and security
- Safety analysis (deterministic and probabilistic)

The R&D program was included as an additional review topic to ensure that it would be adequate to support any new or different features compared with existing CANDU technology (while noting that many aspects of the ACR-1000 design have evolved from proven CANDU engineering). While recognizing that the introduction of new features can improve, for example, reactor safety characteristics, the reliability of SSCs, and plant efficiency, it is important that such features are of a robust design. Therefore, this review placed particular importance on these new features. It is the CNSC expectation that adequate safety must be demonstrated through supporting R&D programs and relevant experience from similar applications to support the introduction of any new SSC design, feature or engineering practice before it is brought into service.

The Phase 2 review assessed the 17 review focus areas to gain a significant level of assurance that AECL has taken into account regulatory requirements and expectations of the CNSC in the design. Consideration was also given to the extent to which generic or outstanding safety issues (for example Generic Action Items) have been resolved. In addition, CNSC staff conducted an audit of the design process that AECL is using for the ACR-1000 at AECL's engineering offices. This was done to verify that the design process is being implemented correctly and in accordance with AECL's policies and procedures.

2.2 Phase 2 Design Review Criteria

For each of the design review focus areas, CNSC staff assessed the submitted documentation against the following requirements and expectations:

- CNSC Nuclear Safety and Control Act and Regulations;
- CNSC Regulatory documents, in particular regulatory document "Design of New Nuclear Power Plants" (RD-337); and
- Canadian CSA Standards and Codes, and International Standards.

2.3 Phase 2 Design Review Findings

CNSC staff acknowledges that, throughout the Phase 2 review, AECL staff was open and transparent in sharing available information, and that they responded diligently to every CNSC request for clarification and additional information.

The CNSC Phase 2 review of the ACR-1000 reactor was a pre-project assessment of a design which is currently in progress and for which certain details have yet to be finalised and confirmed. The Phase 2 review was based mainly on the ACR-1000 Generic Safety Case Report (GSCR) that was produced in June 2008 to

support the design freeze of May 2007. This was done as part of AECL's Basic Engineering Program Phase in which sufficient engineering and safety analysis of the nuclear power plant was completed on a generic level to be ready for project implementation. A GSCR is a higher level non-site specific precursor to a Preliminary Safety Analysis Report (PSAR) which would be submitted as part of an application for a licence to construct for a specific site. A PSAR contains more complete information on the design to demonstrate that it is ready for construction, and more information on the analysis and R&D program to fully demonstrate the adequacy of the design. The PSAR would be developed in parallel with AECL's Project Final Design Phase where the design would be customized based on client-specific and site-specific requirements.

At the request of AECL, CNSC staff's review of the ACR-1000 GSCR was carried out to determine if the level of detail and completeness of the GSCR is that expected of a PSAR. As a result, many of CNSC staff's comments reported in the main body of the report are related to work that would need to be completed to confirm certain aspects of the design or analysis. These would serve to highlight the work of safety significance and thus of CNSC staff's interest. Therefore, all detailed review findings are documented in the main report even if they are not directly related to potential fundamental barriers.

For the Phase 2 review, particular attention was given to the focus areas where:

- There are new features in the design. This was to ensure that AECL has performed or has planned the work for testing and analysis to prove the adequacy of the design; and
- RD-337 as applied to the design of new nuclear power plants sets expectations higher than or departing from past practice. Examples include the adoption of safety goals, application of the single failure criterion for the safety systems and safety support systems, the principles of inherent and passive safety features to minimize sensitivity to events, the reactor control system designed to handle anticipated operational occurrences, the containment designed to cater for severe accidents, and equipment performance during beyond design basis accidents.

During the Phase 2 review, CNSC staff extended the scope of review focus areas to include AECL's R&D program. AECL has provided an overview of the ACR-1000 R&D program in support of the development of the ACR-1000 design, and details for four R&D areas that CNSC staff selected, based on their significance in terms of making a safety case for the ACR-1000 design. The four R&D areas are related to: reactor physics (which was a principal part of the focus review area for reactor core nuclear design), the fuel design, thermal-hydraulics design, and severe accidents to support the containment design.

The ACR R&D program was developed from an assessment of the knowledge base for all aspects of the design. AECL has been conducting the R&D program for product development of the ACR design since the early 2000s.

2.4 Phase 2 Design Review Conclusions

In summary, based on the review of the 17 focus areas, CNSC staff concludes that there are no fundamental barriers to licensing the ACR-1000 design in Canada. It

should be noted that this conclusion is subject to the successful completion of AECL's planned activities, in particular those related to R&D.

This overall conclusion was based on the following findings:

- AECL has provided sufficient design and analysis information for the purpose of the reviews;
- AECL has provided responses to all CNSC staff's Phase 1 comments, and has dispositioned them to CNSC staff's satisfaction. As CNSC staff stated in the Phase 1 report, at a high level, the design intent is compliant with the CNSC regulatory requirements and meets the expectations for new nuclear power plants in Canada;
- CNSC staff's review of the 17 focus areas did not identify any fundamental barriers to licensing the ACR-1000 design in Canada, subject to the successful and timely completion of outstanding R&D, and the resolution of key findings in the focus areas. CNSC staff has provided detailed comments in each of the 17 focus areas and these comments are related to work that staff recommends should be completed before a construction licence decision is made by the Commission. Although these comments do not constitute any potential fundamental barriers, CNSC staff considers that they need to be addressed to confirm actual implementation of CNSC expectations;
- CNSC staff considers an adequate R&D program to be of critical importance in support of a new reactor design; the ACR-1000 design contains a number of new features that require R&D. The overall ACR-1000 R&D program was derived logically from the existing knowledge base and appears to be comprehensive. Also, the R&D program for the four selected topics appears to be adequate. Some key R&D work is in progress and AECL has a plan to complete the work in three phases over a number of years. CNSC staff expects all key safety-related R&D to be completed prior to the submission of an application for a licence to construct. Detailed CNSC review of the adequacy of individual test programs for specific applications was considered beyond the scope of Phase 2;
- For any nuclear power plant the commissioning program plays an important role in verifying that systems, structures and components are correctly installed and will function or operate as intended. This is particularly important for those design features which are new or first-of-a-kind. As part of a licence application, CNSC staff would expect a commissioning program to be submitted that is commensurate with industry best practice that would verify to the extent practicable that new features of the ACR-1000 design will function in accordance with their design requirements.
- In the event that an applicant submits an application for a licence to construct an ACR-1000, CNSC staff would follow-up with the applicant to ensure that all Phase 2 comments for the 17 focus areas are resolved; and
- Safety management during the design process is necessary to ensure that safety is embedded into the design in a conservative, systematic and structured way. CNSC staff reviewed AECL's design process including the Quality Assurance

Manual for the ACR-1000 project, and conducted an audit at the engineering offices of AECL. Overall, CNSC staff concluded that an adequate design process is in place, and has made some observations regarding the implementation of the Quality Assurance program. As part of a licence application, CNSC staff would follow-up with the applicant to ensure that all audit findings have been adequately addressed.

In addition, the Phase 2 review has permitted CNSC staff to gain a more complete understanding of the ACR-1000 design and allowed AECL to gain further insight into the application of RD-337 to the design. The results of this review can be used by staff to guide any future licensing review and has permitted the identification of some key topics that CNSC staff would pursue in greater depth during any future licensing review. This should help to reduce any licensing risk associated with the ACR-1000 design.