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Phase 1 Executive Summary:
Pre-Project Design Review of AECL's Enhanced
CANDU 6 Reactor — EC6



Executive Summary

Background

The Canadian Nuclear Safety Commission (CNSC) is Canada's sole nuclear regulatory agency and operates 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.

A vendor pre-project design review is a high-level assessment of a vendor's reactor technology. It is an optional service provided by the CNSC when requested by a vendor. This service does not involve the issuance of a licence under the NSCA, and it is not part of the licensing process. The conclusions of such reviews will not bind or otherwise influence the decisions made by the Commission.

The review is solely intended to provide early feedback on the acceptability of a nuclear power plant design, based on Canadian regulatory requirements and expectations. The CNSC will require a much more detailed review of the design and safety case for a specific application and a specific site.

Atomic Energy of Canada Limited (AECL), a vendor of nuclear power plants (NPPs), is designing a two-unit Enhanced CANDU-6 reactor (EC6) NPP, each unit with a gross electrical output of 725 megawatts. The EC6 design is largely based on the design concepts and the reactor and process system designs of current CANDU plants. Despite these similarities, there are some significant differences between the EC6 design and existing CANDU technologies.

In January 2009, AECL requested the CNSC to perform a Phase 1 pre-project design review of the EC6 design, and a Service Agreement was then signed between the two organizations. The Service Agreement outlines the objectives, the technical scope of the review, the schedule guideline, the organizations' deliverables, costs, working arrangements and general conditions.

Objectives and Review Phases

The objectives of a pre-project design review are to:

- assess whether a reactor design is, at an overall level, compliant with the CNSC regulatory requirements
- assess whether the design meets the CNSC's expectations for new nuclear power plants in Canada
- identify potential fundamental barriers to licensing a reactor design in Canada

To achieve the above stated objectives, the CNSC staff assesses the safety and security aspects of the design. This 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 the design with regulatory requirements and expectations. Such a review will help increase regulatory certainty and ultimately contribute to public safety.

The pre-project design review process is divided into two phases.

- **Phase 1:** This phase is an overall assessment of the information submitted in support of a reactor design against the CNSC regulatory requirements and regulatory documents. Its purpose is to determine whether the design intent is compliant with CNSC requirements and meets the CNSC's expectations for the design of new nuclear power plants in Canada;
- **Phase 2:** Subsequent to Phase 1, this phase goes into further detail with a focus on identifying whether there are any potential fundamental barriers to licensing the reactor design in Canada. It should be noted that the findings from the Phase 1 review do not in any way prejudice the conclusions of the Phase 2 review.

The Phase 1 pre-project design review for the EC6 is now complete, and the principal findings are provided in the following pages.

Phase 1 Review Process and Selected Review Topics

To facilitate the Phase 1 review, AECL submitted documentation in support of the EC6 design, including documents demonstrating how the NPP design meets the regulatory requirements and expectations of the CNSC. Supporting documents included the Compliance Assessment of the EC6 design against regulatory document *Design of New Nuclear Power Plants (RD-337)*, the EC6 Technical Description, a CANDU 6 generic Safety Analysis Report, and other design documentation.

For the Phase 1 review, the CNSC staff selected 17 review topics to assess the EC6 design, including safety principles, specific design expectations of systems, structures and components important to safety, the robustness of the design against malevolent acts, and a safety analysis that demonstrates the adequacy of the design. The review of these topics is performed to ensure that fundamental safety functions — such as reactor control, reactor shutdown, reactor core cooling, and confinement of radioactive material — are designed to meet CNSC regulatory requirements and expectations for new nuclear power plants in Canada.

Other review topics included an assessment of radiation protection, protection from fire, protection against out-of-core criticality, quality assurance, safeguards, security, and human factors engineering. In addition, initial consideration was given to the extent to which generic or outstanding safety issues have been resolved, and the knowledge for new or innovative design features in the EC6 design has been established.

Phase 1 Review Criteria

To assess the review topics, the CNSC staff primarily used a set of criteria stated in RD-337 — a document providing technology-neutral design expectations. Some of the review topics were also assessed against some specific Canadian regulatory documents and standards, such as the *Radiation Protection Regulations*, the regulatory document *Safety Analysis for Nuclear Power Plants* (RD-310), and the Canadian national standard *Design Quality Assurance for Nuclear Power Plants* (CSA N286.2).

Phase 1 Review Findings

The EC6 is based upon the proven CANDU 6 design. It incorporates features common to many CANDU designs that have been operating successfully both in Canada and abroad. The reference design of the EC6 is the Qinshan CANDU 6 NPP, designed in the late 1990s by AECL.

The CNSC staff considers EC6 to be a new nuclear power plant and as such, modern requirements and expectation are applicable. These include CNSC regulatory documents for design and analysis of new NPPs (for example, RD-337, RD-310 and S-294), and modern codes and standards (for example, the most recent versions of CSA standards). As a result, AECL has introduced a number of changes to the current Qinshan CANDU 6 design so that the EC6 design can satisfy modern expectations for the design and analysis of new NPPs.

In its review, the CNSC staff paid particular attention to each of the review topics where:

- RD-337, RD-310 and S-294 set 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 respond to anticipated operational occurrences, the containment designed to address severe accidents, and equipment performance during beyond design basis accidents;
- New design features and provisions are being introduced into the EC6 design to meet the most recent design expectations. This was to ensure that AECL has performed or has planned the work for testing and analysis to prove the adequacy of such new features and provisions.

It should be noted that AECL is at an early stage of implementing changes into the EC6 design. Some key design documentation specific to the EC6 design was made available to the CNSC staff. Other supporting assessments, analyses and documentation specific to EC6 are being developed and were not available to the CNSC staff during this Phase 1 review. Therefore, the EC6 specific information was supplemented by more generic information, such as the reference CANDU 6 Safety Analysis Report, which does not necessarily reflect the final EC6 design.

Based on the Phase 1 pre-project review of the documentation submitted, the CNSC staff concludes that:

- AECL has, in general, provided sufficient design and analysis information for the purpose of this review;
- At an overall level, the design intent is compliant with the CNSC regulatory requirements and meets the expectations for new nuclear power plant designs in Canada. This conclusion would be further confirmed during a Phase 2 review, when required information for open specific technical items identified for each review topic will be fully addressed. The CNSC staff anticipates that these items could be brought to closure during a Phase 2 review.

With reference to the specific technical items for each review topic that require further information, the CNSC staff has made a number of observations, the most significant of which are the following:

- Generic design documentation must be updated to reflect the specifics of the EC6 design. In particular:
 - A preliminary Safety Analysis Report for the EC6 design would be needed for a Phase 2 review, to confirm that the expectations in RD-310, RD-337 and S-294 are met;
 - Complete and accurate documentation of the reactor core design and core nuclear performance is required, including verification using modern validated computational tools.
- Further information is required on the effectiveness of the defence-in-depth design provisions for reactivity control;
- Clarification is required as to how the code classifications of systems, structures and components take into account safety classification;
- Further demonstration is required on the capability of the reactor control systems to handle anticipated operational occurrences without requiring protective action;
- Further information is needed regarding conformance with the clauses of RD-337 related to the design of the containment and associated mitigating and complementary features for severe accidents;
- Research and development information is needed to ensure that specific design features are proven, including adequate support for the severe accident mitigation strategy proposed for the in-vessel retention of molten core debris;
- Further information is required on the likelihood and severity of consequences of events with failure to shutdown or ineffective action of the shutdown systems;
- Confirmation that the value of peak ground acceleration used for seismic protection for the EC6 design is adequate;
- Confirmation of the development and implementation of a fire protection program;

- A detailed demonstration that there is a process to ensure that the expectations for Safety Management during Design and Human Factors Engineering of RD-337 are systematically implemented.

Notwithstanding the observations above, CNSC staff is of the opinion that these findings are likely resolvable during a Phase 2 review.