Canada's Nuclear Regulator

June 2013

Phase 2 Executive Summary
Pre-Project Design Review of Westinghouse AP1000 Reactor Design

Canadian Nuclear Safety Commission
Commission canadienne de sûreté nucléaire

Canada

Executive Summary

A vendor pre-project design review of a new nuclear power plant provides an opportunity for 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 if 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.

The CNSC completed a Phase 1 review of the Westinghouse AP1000 reactor design in January 2010, and concluded that, at an overall level, the design intent complied with the CNSC's regulatory requirements and expectations. A recently completed Phase 2 review of the AP1000 design provides a further level of assurance that Westinghouse has taken regulatory requirements and expectations into account. Based on the Phase 2 review, CNSC staff conclude that there are no fundamental barriers to licensing the AP1000 design in Canada. It should be noted that this is subject to the resolution of key findings from the Phase 2 review related to Beyond Design Basis Accidents and severe accidents, robustness and security, as well as Westinghouse's commitment to a design upgrade of the control systems and facilities to meet the RD-337 requirements related to the means of reactor shut down.

1.0 Background

1.1 Introduction

The Canadian Nuclear Safety Commission (CNSC) is Canada's sole nuclear regulatory agency and operates under the *Nuclear Safety and Control Act* (NSCA). 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 proposed 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 license under the NSCA and is not part of the licensing process. The conclusions of such reviews will not bind or otherwise influence decisions made by the Commission Tribunal.

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 would require a significantly more detailed review of the design and safety case in case of a specific application for a license to construct a nuclear power plant at a particular site.

Westinghouse Electric Company (WEC), a vendor of nuclear power plants, has designed the AP1000 pressurized water reactor (PWR), which has a net electrical output of about 1117 megawatts. The AP1000 design builds on traditional PWR technology featuring passive safety systems and a number of plant simplifications in respect to the earlier reactor models. WEC has stated that these features enhance the safety of the plant. The AP1000 design contains a number of unique technical solutions and relies on passive safety systems and features, and is regarded as an "advanced passive plant design".

In November 2008, WEC requested that the CNSC performs a Phase 1 pre-project design review of the AP1000, and a Service Agreement was then signed between the two organizations. A Phase 1 review was completed, and the Phase 1 review report was issued in January 2010.

In September 2012, WEC and CNSC signed a Service Agreement for a Phase 2 review of the AP1000 reactor design.

1.2 Design Review Objectives

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

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

A vendor pre-project design review provides an opportunity for CNSC staff to assess the design prior to any licensing activities, and to identify for resolution potential issues in relation to the compliance of the design with the Canadian 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 design review process is divided into three phases:

- **Phase 1: Assessment of Compliance with Regulatory Requirements.** This phase is an overall assessment of the information submitted in support of a reactor design against CNSC regulatory requirements and expectations. 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: Identification of Fundamental Barriers to Licensing.** 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 Phase 1 review do not in any way prejudge the conclusions of Phase 2 review.

- **Phase 3: A follow up to Phase 2.** This phase focuses on a more detailed review of selected topics identified by the vendor.

The Phase 2 pre-project design review for the AP1000 is now complete and key findings are provided below.

1.4 Definition of Fundamental Barriers to Licensing

CNSC staff consider a fundamental barrier to licensing of a new reactor design as a deficiency of the design or the design process that, if not corrected, could have the potential for significant risk to the public, workers or the environment. The barrier is considered fundamental when there is no clear and adequate path to resolution of a significant safety issue. The barrier would be also considered fundamental if there were significant uncertainties associated with the proposed resolution plan or if the timeline was such that the issue could not be resolved at the time of an application for a license to construct.

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

- non-compliance with Canadian legal requirements
- unjustified non-conformance with Canadian regulatory requirements including those in the regulatory document RD-337, and other applicable regulatory documents and national standards for technical 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 (i.e., not adequately supported by analysis, research and development, or both)
- a design for which operational compliance introduces unacceptable operational complexity

2.0 Phase 2 Review

2.1 Phase 2 Review Process and Selected Review Topics

To facilitate the Phase 2 review, WEC submitted an AP1000 Design Control Document (DCD Rev. 19), similar to a Safety Analysis Report, providing a technical description of the design and

information on the safety analysis. A number of supporting documents for the AP1000 design were also provided, including documents demonstrating how the nuclear power plant design meets the regulatory requirements and expectations of CNSC. WEC also submitted the AP1000 Core Reference Report reflecting core and fuel design changes beyond DCD Rev. 19. As such, DCD Rev. 19 as supplemented by the Core Reference Report reflects accumulated AP1000 design changes and is a complete update of the accident analyses documented in Chapter 15 of the DCD document.

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
- issues that could lead to potential fundamental barriers

CNSC staff selected 20 review topics to assess the AP1000 design, as listed below. The topics were reviewed to confirm that fundamental safety functions — such as reactor control, reactor shutdown, reactor core cooling, and confinement of radioactive material — are designed to meet the CNSC's regulatory requirements and expectations for new nuclear power plants in Canada.

Review topics:

- Defense in depth, safety goals and objectives dose acceptance criteria
- Classification of Systems Structures and Components
- Reactor core nuclear design
- Fuel design and qualification
- Control system and facilities
- Means of reactor shutdown
- Emergency core cooling and emergency heat removal systems
- Containment and safety important civil structures
- Beyond Design Basis Accident (BDBA) and severe accident prevention and mitigation
- Safety analysis
- Pressure boundary
- Fire protection
- Radiation protection
- Out-of-core criticality
- Robustness, security, and safeguards
- Vendor's research and development program
- Management system of design process and QA in design and safety analysis
- Human factors
- Incorporation of decommissioning into design considerations

Another topic was added to the standard set of review topics - the implications for the design as a result of lessons learned from the nuclear accident at Fukushima Daiichi on March 11, 2011. It is

expected by CNSC that reactor vendors identify lessons learned from this event and modify their designs as needed.

CNSC staff paid particular attention to:

(i) the knowledge of the new or innovative design features and the extent to which outstanding safety issues and generic action items for the existing PWR technology have been resolved for the AP1000 design, including provision for the associated research and development program

(ii) design provisions for severe accident prevention and mitigation. CNSC staff expects the vendor's research and development program to support any new or different features as compared to existing PWR technologies so that their adequate safety is demonstrated.

The review results were ranked using the following scheme:

- *Potential Fundamental Barriers to Licensing* (defined in Section 1.4);
- *Key Findings*, defined as:
  - exceptions from CNSC regulatory expectations contained in regulatory documents such as RD-337, RD-310
  - lack of supporting information on conformance with CNSC design expectations or cases when regulatory expectations are met with small margins (e.g. detailed analysis is required and cannot be performed during the pre-project review)
- *Technical Clarification*, defined as:
  - lack of information due to supporting documents that have not been submitted
  - concerns about completeness, sufficiency and quality of submitted documents
  - concerns about a particular minor technical aspect of the design

In addition, CNSC staff conducted an audit of the WEC's design process used in the AP1000 design. This was done to verify that the design process has been implemented correctly and in accordance with WEC's policies and procedures.

2.2 International Collaboration of Regulatory Authorities

The Multi-national Design Evaluation Program (MDEP) is a joint effort of several national regulatory authorities to enhance the safety of new reactor designs through various joint activities. Canada is a member of MDEP and the MDEP AP1000 Working Group.

Within the MDEP collaborative activities, a series of CNSC – US NRC video conferences / technical discussions on the eleven (11) AP1000 Phase 2 focus topic issues were held, with other MDEP AP1000 Working Group members' participating in the discussions.

The following focus topics were discussed in depth:

- Classification of Structures, Systems and Components
- Control Systems and Facilities
- Emergency Core Cooling and Emergency Heat Removal Systems
- Containment and Civil Structures Important to Safety
- Safety Analysis
- Fire Protection
- Robustness and Seismic Issues
- Computer Code Analysis
- Management System of Design Process and Quality Assurance in Design and Safety Analysis
- Human Factors

The discussions on many selected issues were successful and beneficial, and helped CNSC staff to identify areas where similarity or divergence of respective national regulatory requirements between the United States Nuclear Regulatory Commission (U.S. NRC) and CNSC regulatory frameworks may exist.

2.3 Phase 2 Design Review Criteria

To assess the review topics, CNSC staff primarily used the same set of criteria as in the Phase 1 review. These criteria are stated in regulatory document *RD-337: Design of New Nuclear Power Plants* —which provides technology-neutral design expectations. A limited number of review topics were assessed against some specific Canadian regulatory documents and standards such as:

- *Radiation Protection Regulations*
- RD 310: *Safety Analysis for Nuclear Power Plants*
- CSA N286.2*: Design Quality Assurance for Nuclear Power Plants*

2.4 Other Phase 2 Design Review Considerations

WEC has introduced many novel elements into the AP1000 design, such as passive safety features, squib valves, canned reactor coolant pumps, in-vessel retention of a core melt as a severe accident management concept, and modular construction of the steel containment vessel so that the AP1000 design can satisfy modern expectations for the design and safety analysis of new nuclear power plants.

In their Phase 2 review, CNSC staff paid particular attention to each of the review topics where:

- RD-337, RD-310 and S-294: *Probabilistic Safety Assessment for NPPs* set expectations higher than or departing from the 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 complementary design features, 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

- the design changes, new design features and provisions are introduced into the AP1000 design to meet the most recent design expectations. The review focus was to confirm that there is a link to the proposed AP1000 research and development program and plans for testing and analysis to prove the adequacy of such new features and provisions
- outstanding safety issues and generic action items for the existing PWR technology are implicated

2.5 Phase 2 Design Review Results

CNSC staff acknowledges that, throughout the Phase 2 review, WEC's staff was open and transparent in sharing available information on many focus topics, by responding diligently to CNSC requests for clarification and additional information. However, for two focus topics (robustness/security, as well as BDBA and severe accidents), due to US NRC security issues, the transfer of information between WEC and CNSC has not been possible affecting the review. By mutual WEC and CNSC decision these focus topics will be followed in more detail at the next phases of the review.

CNSC and WEC have agreed that the issues of the information transfer must be solved before the next phase of the review.

The CNSC/U.S. NRC collaboration with MDEP helped CNSC staff to better understand the US design certification process, and identify areas of similarities or divergence of the respective national regulatory requirements. Thus, CNSC review findings reflect these identified differences.

The *Key Findings* resulting from the Phase 2 review can be summarized as follows:

- An in-depth review of robustness and physical security aspects of the AP1000 design will be conducted at the future review phases once issues of transfer of security-protected information between the CNSC and WEC are resolved.
- More information from WEC is needed for in-depth review of the BDBA and severe accident phenomena and mitigating strategies at the future review phases.
- WEC committed to an upgrade of the control system and facilities design to comply with RD-337 requirements related to safety systems sharing of instrumentation, means of reactor shut down and prevention of cross-links between levels of defense-in-depth. The CNSC will

assess the implementation of these upgrades onto AP1000 design at the future review phases.

- WEC is expected to address the quantitative safety goals of small and large release frequencies according to RD-337 requirements which differ from those of the U.S. NRC.
- The focus topic of out-of-core criticality requires further justification from WEC with respect to re-criticality accident analysis as given by RD-327: *Nuclear Criticality Safety*.
- AP1000 dose acceptance criteria for different operational states including Design Basis Accidents are those of the U.S. NRC. WEC should provide further evidence of meeting the Canadian dose limits as given in RD-337.

2.6 Phase 2 Design Review Conclusions

In summary, CNSC has not identified fundamental barriers to AP1000 licensing in Canada at the high level of the Phase 2 review. Further design assessment will be conducted as part of future Phase 3 or Construction License Application phases.

This overall conclusion was based on the following:

- CNSC staff's review of the 20 review topics uncovered a number of key findings mostly related to differences between the U.S. NRC and CNSC regulatory design requirements; however, the CNSC / WEC Phase 2 review discussions led to defining mutually agreeable paths forward towards their resolution.
- WEC has committed to a design upgrade of the control system and facilities in order to meet the RD-337 requirements related to safety systems sharing of instrumentation, means of reactor shut down and prevention of cross-links between levels of defense-in-depth.
- WEC has committed to resolving the information transfer issues for the next phases of the review.
- The in-depth review of the focus topics affected by the information transfer problems will be carried out by CNSC at the future design review phases.

The CSNC will follow up on all Phase 2 review commitments by WEC at the future design review phases.