# PRE-LICENSING OF THE ADVANCED CANDU REACTOR®

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**Abstract** – Atomic Energy of Canada Limited (AECL) developed the Advanced CANDU Reactor™-700 (ACR-700™) as an evolutionary advancement of the current CANDU 6® reactor. As further advancement of the ACR design, AECL is currently developing the ACR-1000™ for the Canadian and international market. The ACR-1000 is aimed at producing electrical power for a capital cost and a unit-energy cost significantly less than that of the current generation of operating nuclear plants, while achieving shorter construction schedule, high plant capacity factor, improved operations and maintenance, increased operating life, and enhanced safety features. The reference ACR-1000 plant design is based on an integrated two-unit plant, using enriched fuel and light-water coolant, with each unit having a nominal gross output of about 1200 MWe.

AECL initiated pre-licensing reviews of the ACR reactor design in Canada, US and China, with an objective to take into account regulatory feedback early in the design process.

The Canadian Nuclear Safety Commission (CNSC) is performing a pre-project pre-licensing assessment of the ACR design. The objective of the assessment is to issue a formal statement as to whether there are any fundamental barriers that would prevent the licensing of the new CANDU reactor design in Canada under the Nuclear Safety and Control Act. The CNSC review is being conducted in four phases. In Phase 1 (September 2003 to September 2004) CNSC performed a pre-licensing review of the ACR-700, and focused on the design process, methodology, design concepts and R&D. CNSC staff reviewed about 100 reports, and submitted to AECL questions and comments. In Phase 2 (September 2004 to August 2005) AECL provided responses and additional information to CNSC on their comments and questions in Phase 1. Phase 3 is the Transition Phase (September 2005 to May 2006), bridging the transition from the ACR-700 to the ACR-1000 design. Phase 3 focused on review of generic aspects of the ACR design, on the Safety Analysis methodology, and on review of the draft CNSC design requirements for new reactor designs. In Phase 4 (June 2006 to June 2009) AECL will prepare and submit to CNSC the documents that constitute the Preliminary Safety Case Package for ACR-1000, and CNSC will issue the Licensability Assessment Report.

## 1. INTRODUCTION

Atomic Energy of Canada Limited (AECL) developed the Advanced CANDU Reactor™-700[1] (ACR-700™) as an evolutionary advancement of the current CANDU 6®[2] reactor. As further advancement of the ACR design, AECL is currently developing the ACR-1000™[1] for the Canadian and international market. The ACR-1000 is aimed at producing electrical power for a capital cost and a unit-energy cost significantly less than that of the current generation of operating nuclear plants, while achieving shorter construction schedule, high plant capacity factor, improved operations and maintenance, increased operating life, and enhanced safety features. The reference ACR-1000 plant design is based on an integrated two-unit plant, using enriched fuel and light-water coolant, with each unit having a nominal gross output of 1200 MWe.

The ACR-1000 design has evolved from AECL's in-depth knowledge of CANDU systems, components, and materials, as well as the experience and feedback received from owners and operators of CANDU plants. The ACR design retains the proven strengths and features of CANDU reactors, while incorporating innovations and state-of-the-art technology. It also features major improvements in economics, inherent safety characteristics, and performance, while retaining the proven benefits of the CANDU family of nuclear power plants.

The CANDU system is ideally suited to this evolutionary approach since the modular fuel channel reactor design can be modified, through a series of incremental changes in the reactor core design, to increase the power output and improve the overall safety, economics, and performance.

The safety enhancements made in ACR-1000 encompass improved safety margins, performance and reliability of safety related systems. In particular, the use of the CANFLEX®[3]-ACR fuel bundle, with lower linear rating and higher critical heat flux, provides increased operating and safety margins. Safety features draw from those of the existing CANDU plants (e.g., the two independent shutdown systems), and other features are added to strengthen the safety of the plant (e.g., a passive gravity-driven water supply from a reserve water system to provide various back-up heat sinks). These and other safety improvements serve to reduce the licensing risk of the design.

## 2. ACR-1000 LICENSING OBJECTIVE

The AECL licensing objective for the ACR-1000 is to support the overall objective of a successful deployment in Ontario. To achieve this, a pre-licensing review is being undertaken with the Canadian Nuclear Safety Commission (CNSC). AECL's goal of the pre-licensing review is aimed at obtaining a positive licensability statement for the ACR-1000, thereby reducing the licensing risk at the time of project commitment with a utility in Ontario.

AECL and CNSC signed a Memorandum of Understanding (MOU) in November 2005, which defined four phases of the ACR pre-licensing review.

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[2] CANDU® (CANada Deuterium Uranium) is a registered trademark of Atomic Energy of Canada Limited (AECL).

[3] CANFLEX® is a registered trademark of AECL and the Korea Atomic Energy Research Institute (KAERI).

In Phase 1 (September 2003 to September 2004) CNSC performed a licensability review of the ACR-700, and focused on the design process, methodology, design concepts and R&D. CNSC staff reviewed about 100 reports, and submitted to AECL questions and comments. In Phase 2 (September 2004 to August 2005) AECL provided responses and additional information to CNSC on their comments and questions in Phase 1. Phase 3 is the Transition Phase (September 2005 to May 2006), which occurred during the transition from the ACR-700 to the ACR-1000 design. Phase 3 focused on review of generic aspects of the ACR design, the Safety Analysis methodology, and on review of the draft CNSC design requirements for new reactor designs. In Phase 4 (June 2006 to June 2009) AECL will prepare and submit to CNSC the documents that constitute the Preliminary Safety Case Package for ACR-1000, and CNSC will issue the Licensability Assessment Report.

AECL's primary objectives for the pre-licensing are to:

1. Identify any potential regulatory issues early in the design, so there is time to address them before project commitment;
2. Provide a reasonable assurance to a utility that the licensing risk to cost and schedule of the project from licensing is acceptable before a project is committed; and
3. Use the results of pre-licensing in the project review, so the latter takes less time.

## 3. LICENSING MILESTONES

In order to reach its goal in support of a successful deployment of the ACR-1000 in Ontario, a number of specific major milestones have to be accomplished. These milestones are:

1. Obtain from CNSC a licensability statement. The current ACR schedule date for CNSC to issue a statement of licensability is June 2009.
2. Obtain a Site Preparation Licence (Permit). A site preparation licence granted by the CNSC is a prerequisite to the start of major equipment procurement, and to the start of site preparation. It is issued after a positive decision is obtained regarding the Environmental Assessment.
3. Obtain a Construction Licence (Permit).
4. Obtain an Operating Licence.

## 4. LICENSING OBJECTIVES

In order to meet each of the licensing milestones, the following high-level objectives have to be accomplished.

### 4.1 Submit the Preliminary Safety Case Package

AECL will issue a complete and timely Preliminary Safety Case Package (PSCP) to the CNSC. The PSCP consists of a series of ACR-1000 documents that are scheduled to be issued in the period from January 2006 to March 2008.

Note that the submittal of the PSCP to the CNSC is a *pre-licensing* objective and occurs before the start of an ACR project in Ontario.

### 4.2 Minister's Environmental Assessment Decision

The critical path objective in obtaining the site preparation licence is to have a positive Minister's Environmental Assessment (EA) decision. A pre-requisite to this objective is for AECL (and partners), or a utility proponent, to initiate and complete the EA program task.

Note that the EA process for a new nuclear power plant build assumes a Panel review [1]. The EA requires preparation and submission of design documentation of good quality and adequate detail to the members of the EA Panel for the assessment of the impact on the environment.

### 4.3 Issue Preliminary Safety Analysis Report

The Preliminary Safety Analysis Report (PSAR) is one of the requirements for a construction licence.

### 4.4 Issue Final Safety Analysis Report

The Final Safety Analysis Report (FSAR) is one of the requirements for an operating licence.

## 5. MAJOR LICENSING TASKS AND ACTIVITIES

The major tasks associated with the PSCP are listed below.

### 5.1 Memorandum of Understanding and Continuous Engagement of CNSC

AECL signed the Memorandum of Understanding (MOU) with the CNSC in November 2005. The MOU lists the technical scope and work phases, and the pre-licensing objectives. A support document (ACR Pre-licensing Technical Review Scope) lists all the deliverables that AECL has committed to submit to CNSC, and CNSC will review as part of the ACR pre-licensing.

### 5.2 Review and Trial Use of CNSC's Design Requirements Document

In March 2005, the CNSC issued for trial use the pre-consultation draft "Requirements for Design of Nuclear Power Plants" (DRD). AECL reviewed the draft document and provided CNSC with a list of questions and 19 position papers on topics that required further clarification. CNSC has provided feedback on AECL's position papers and questions.

The DRD will be revised internally by the CNSC and be re-issued for public consultation as a regulatory document. The information contained to date does not represent a final regulatory position on the matter.

During the ACR-1000 Basic Engineering Program (BEP), discussions with CNSC staff will be conducted at the detailed design level to ensure good understanding of the new requirements, and ensure compliance of the ACR-1000 design with the DRD requirements or their intent.

### 5.3 Address and Disposition CNSC's Comments

CNSC issued a number of comment packages during the first phases of the pre-licensing review. AECL responded to those comments. AECL will also be addressing during the BEP any further comments that will be received to ensure the ACR-1000 design meets CNSC requirements.

## 6. LICENSING RISK AND RISK MITIGATION

Certain risks can be identified and associated with the licensing milestones and further down to licensing objectives, tasks and activities. This section identifies the high-level licensing risks and their mitigation strategy.

### 6.1 Uncertainty related to the formal licensing process of the ACR

Most high-level licensing risks are associated with developments regarding the regulatory process and updated requirements. The regulatory framework in Canada is currently in a period of change. Specifically, changes or updates in the CNSC's licensing process in Canada have been covered in a document recently issued by CNSC [1]. For example, ACR-1000 could be the first new nuclear power plant to undergo an Environmental Assessment under the CEAA. Changes in specific regulatory requirements (e.g., DRD) are taking place concurrently, as well.

Risk mitigation activities are on-going to reduce the uncertainty associated with the changing regulatory framework, for example, AECL will start the preparatory work for an EA as early as possible and will engage CNSC in discussions regarding implementation of the DRD requirements for ACR-1000.

## 7. ACR LICENSING BASIS

The ACR-1000 regulatory and licensing approach is to ensure adherence to Canadian and applicable international requirements, codes and standards by providing:

- A plant design that complies with Canadian licensing requirements;
- A plant design that can be readily adapted to meet applicable international requirements without major changes;
- A Quality Assurance (QA) program which satisfies the requirements of the Canadian and applicable international QA codes and standards, as specified by the regulators;
- A plant design that takes into consideration the installation of safeguard and sabotage preventive systems to meet Canadian and international requirements, and to satisfy the safeguards requirements of the International Atomic Energy Agency (IAEA).

The ACR-1000 design will comply with the nuclear regulatory policies and requirements within Canada and will consider regulatory policies in other potential market countries that may have an impact on the design.

### 7.1 Regulatory Compliance and Licensing

The licensing process for nuclear reactors in Canada is the means by which the CNSC gains assurance that a nuclear facility will be sited, designed, constructed, commissioned, operated and decommissioned in compliance with safety criteria and requirements established by the CNSC based on the Canadian Nuclear Safety and Control Act.

To ensure ACR-1000 is licensable in Canada, the following requirements and activities are set:

- The ACR-1000 plant will be designed to fulfill all applicable Canadian regulatory requirements including taking into account the proposed CNSC Requirements for Design of Nuclear Power Plants.
- The design will comply with all applicable Canadian codes and standards.
- Design solutions will be provided for Generic Action Items (GAIs). Direct design solutions for GAIs will be implemented and, for issues where direct design solutions may not be feasible, AECL will provide assurance that the major contributors to risk and the major sources of uncertainty associated with the issue have been identified and addressed.

A pre-licensing review of the ACR is conducted with the CNSC during the Basic Engineering Program (BEP) phase as previously noted. Issues raised by the CNSC during the review will be addressed by design or provision of design support information such that no fundamental barriers exist.

To ensure the design is licensable internationally the following licensability requirement is set:

- Regulatory policies and requirements from other target-market countries and the IAEA will be reviewed, and where applicable, the ACR-1000 design will either comply with these requirements, or where this would adversely impact meeting one or more of the other objectives for the Canadian market, the design will be made readily adaptable to meet the regulatory requirements of other jurisdictions and the IAEA.

In this respect the IAEA Safety Standards Series Requirements Document NS-R-1 [2] will be used in the ACR-1000 design.

## 8. ACR PRE-APPLICATION REVIEW IN THE US

Between mid-2002 and 2005 AECL Technologies (AECLT, a wholly owned US subsidiary of Atomic Energy of Canada Limited) was the proponent of pre-application review of the ACR-700 design with the US Nuclear Regulatory Commission (NRC) in the United States.

Under the pre-application review, 13 focus topics were established for NRC review and about 25 technical meetings were held. Approximately 35 formal documents and more than 300 additional supporting documents were submitted during this time for NRC review.

The results of the NRC's staff pre-application review have been documented in a Pre-Application Safety Assessment Report (PASAR) [3] that has been issued in October 2004. The review conclusions by USNRC staff as documented in the PASAR report are as follows:

"On the basis of its review of the materials submitted by AECL, including responses to requests for additional information, the staff concludes that the applicant will need to pursue a number of technical issues in more detail to reach satisfactory conclusions for design certification. The policy, regulatory, and technical issues involved are complex. Notwithstanding, based on the information provided, the staff believes at this time that AECL will ultimately be able to satisfactorily address these policy, regulatory, and technical issues during the design certification review."

## 9. ACR PRE-APPLICATION REVIEW IN CHINA

Pursuant to the bilateral agreement between AECL and the Chinese nuclear regulator, National Nuclear Safety Administration (NNSA) and its technical supporting organization, Nuclear Safety Center (NSC), the NNSA/NSC will be reviewing the ACR-1000 in the following seven focus areas:

1. ACR Licensing basis;
2. Safety Important Structures and Components;
3. Reactor Core;
4. Safety Important Fluid Systems (Including Primary Loop Systems, Safety Systems, and Radioactive Waste Management Systems, etc.);
5. Instrumentation and Control as well as Electrical Power Systems;
6. Design Basis Accidents and Severe Accidents; and

7. Probabilistic Safety Assessment.

The main objective of the pre-application review by NNSA/NSC is to review ACR's compliance with the Chinese regulatory requirements.

The scope of the pre-application review by the NSC staff includes the following:

- Review key design requirements and methodology documents of ACR to identify potential design and analysis areas in which compliance with Chinese regulations is not readily apparent, and
- Perform a follow-up review of selected issues identified during Qinshan III licensing process.

The NSC review is focused on the following ACR documentation: Design Requirements, Methodologies, Safety Basis, Criteria, Tools, Assumptions, R&D plan, and Verification plan.

To facilitate the review, the NSC is sending its experts to CNSC for in-depth familiarization with the ACR design and participation in the ACR technical review being performed by CNSC. The ACR pre-application review will also benefit from past experience in successfully licensing CANDU 6 in China.

## 10. CONCLUSIONS

The Canadian Nuclear Safety Commission is currently performing a pre-licensing review of the Advanced CANDU Reactor design to assess its licensability in Canada. The first phase of the pre-licensing review was focused on the ACR-700 design. The second phase of the pre-licensing review will focus on the ACR-1000 design. The licensability review will not constitute a licence, but in AECL's view will provide a reasonable assurance to a utility that there will be no fundamental barriers to licensing ACR-1000.

## References

1. "Licensing Process for New Nuclear Power Plants in Canada", CNSC, INFO-0756, February 2006.
2. "Safety of Nuclear Power Plants: Design, Safety Requirements", NS-R-1, IAEA, Vienna, 2000.
3. "Pre-Application Safety Assessment Report related to the Advanced CANDU Reactor 700 MWe", USNRC, October 2004.