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Abstract

To date the licensing experience with CANDU has been relatively good, with plants successfully licensed both domestically and in other countries. Nevertheless it is now clearly recognized that the utilities need more formal evidence that the licensing risk is low, if they are to proceed with new nuclear power projects.

In response AECL pioneered "up-front" licensing. The 450 MWe CANDU 3 product was executed as a Standard Product Design, with the intention of completing all the conceptual design and most of the detail design before project commitment. The Canadian nuclear regulator, the Atomic Energy Control Board (AECB), was invited to begin licensing review at the early stages of the CANDU 3 conceptual design. A series of licensing milestones was defined as follows:

1. Licensing Basis
2. Identify Potential Problems
3. No Major Problems Foreseen, and
4. Accept Standard Design

Currently Milestones 1 and 2 are almost complete. Milestone 3 requires resolution of all AECB-identified issues and actions, and when complete, provides the equivalent from a design point of view of a construction license for the standard design. When a site is selected, only site specific licensing will be required in order to obtain the actual construction license. From a design point of view, Milestone 4 is the equivalent of the operating license for the standard design.

The more recent CANDU 9 programme is centred on an evolutionary design of approximately 900 MWe. It is based on already-operating CANDUs, with improvements in the areas of constructability, economics, plant layout, operations and maintenance, and safety. Even so, both domestic and foreign potential users require evidence of licensability in Canada as of "today". An "up-front" licensing process, using a modified CANDU 3 model, has been established to give this assurance. For CANDU 9, this involves a two-year intensive review by the AECB, which will end in January 1997.

The documents submitted for review encompass all the safety design requirements, design requirements and design descriptions of the major systems, a preliminary Safety Analysis Report, a preliminary Probabilistic Safety Assessment, a Human Factors Programme Plan, the procedures for producing safety-critical software, and others. The review scope includes comparison of the design and safety assessment results with current licensing requirements. Each document, or group of documents, receives a formal written response from the AECB, so that both parties can measure the progress. An agreed dispute resolution mechanism involving

senior managers and Executives of both AECL and the AECB kicks in when there is disagreement on major items. The review will be complete once there is a finding that there are “no fundamental barriers” to licensability in Canada. This is sufficient to allow foreign regulators to proceed with detailed licensing with confidence, and therefore assures utilities in Canada or overseas that they can proceed with a project with minimal licensing risk.

1. Introduction

Modern utilities view nuclear power more and more as a commodity—it must compete “today” with current alternatives to attract their investment. With its long construction times and large capital investment, nuclear plants are vulnerable to delays once they have been committed. Delays can come from a number of sources - labour strikes, technical “surprises”, poor project management, intervention by special-interest groups, and regulatory licensing. For nuclear power to succeed in this era of cheap fossil fuels, each of these sources of risk must be countered. Reduction of licensing risk for CANDU is the subject of this paper.

There are two related issues. Where the purchaser and the regulator are experienced in CANDU, the thrust is a very practical one: to identify and resolve major licensing risks at a very early stage in the project. Thus for a Canadian project, the designer (AECL) and the prospective purchaser would deal directly with the AECB. However CANDU has also been successfully licensed in other countries, including Korea, Romania, Argentina, India and Pakistan. Each of these countries has its own regulatory agency responsible for licensing the plant. In addition, however, the foreign customer and regulator may seek input from the AECB, up to and including a statement of licensability in Canada; this is not normally needed for a “repeat” plant and/or if the customer is experienced in CANDU, but can be requested if the plant configuration has been modified significantly from an already-operating CANDU. It is thus the responsibility of the designer to initiate early discussions with the AECB so the foreign CANDU meets the expectations of its customers.

2. Canadian Licensing Process

The licensing process followed for many years in Canada¹ has three formal steps, similar to those in other countries. First comes Site Acceptance, initiated by a formal Letter of Intent to the AECB. From the regulatory viewpoint, Site Acceptance confirms the suitability of the site for a nuclear power plant, whose conceptual design is presented at this point. More recently, an environmental assessment is required as part of Site Acceptance to ensure public knowledge of the proposal and to confirm that the environmental effects are acceptable. The next step is Construction Approval, supported by a preliminary design and safety analysis. Key documents reviewed at this stage include all the design requirements documents (for example, Safety Design Guides) and the Preliminary Safety Report. The third step is granting of an Operating Licence, supported by the detailed design documentation, a Final Safety Report, a commissioning programme, operating policies and principles, emergency plans, authorization of operators, etc.

The Canadian licensing philosophy places the fundamental responsibility for safety on the plant owner, with the AECB acting in an audit role. The AECB sets overall safety objectives which the design must satisfy, but to a large extent leaves the means to satisfy these objectives up to the designer. It does of course exercise independent and informed judgement as to whether the design will meet the overall safety objectives with reasonable confidence. This approach has two benefits: it encourages innovation, and avoids the potential conflict of the regulator sitting in

judgement on its own design rules. On the other hand, there is a potential for licensing delays and/or added costs if there is a misunderstanding of what the requirements mean, or what constitutes an adequate method of meeting them. However past U.S. experience has shown that highly prescriptive regulatory design requirements do not obviate this problem, especially when the requirements are subject to rapid change and escalation.

To address this uncertainty, a better process was sought that would give more assurance to owners of a smoother licensing process, and to regulators that requirements would be well-defined up-front so that the potential for misunderstanding is reduced. These concepts, although initiated on a proposed second unit at the Lepreau site in New Brunswick, came to fruition with the CANDU 3 Standard Product Design programme, described in the next section.

3. CANDU 3 Experience

CANDU 3 is a small (450 MWe) evolutionary single-unit plant aimed at utilities with small electrical grids and “first-time” nuclear buyers. It is a Standard Product Design. The goal was to do all the conceptual and most of the detailed design, and obtain assurance of licensability, before a site-specific project was committed. This will give an assurance of low risk to potential customers.

Reduction of licensing risk was addressed from the beginning. AECL formally asked the AECB to engage in pre-licensing of the CANDU 3 Standard Product Design^{2 3}, and submitted documents describing the design to date and how we thought the licensing process could proceed.

Milestones

AECL and the AECB agreed that pre-licensing of the CANDU 3 design would use a process of four Milestones, listed in Table 1 and described as follows.

1. Licensing Basis

This first Milestone defined the basis for the licensing requirements, and required the submittal of fourteen documents:

- a Licensing Basis Document (LBD), the top level document which identifies, among other things, the codes, standards and regulatory documents which will govern;
- twelve Safety Design Guides (SDGs), covering a number of topics such as tornadoes, fire, earthquakes, etc. which designers use to ensure proper and systematic application of safety in design;
- a systematic review of the plant design to identify all possible initiating failures, as required by AECB document C-6⁴ which defines how safety analysis shall be performed.

Achieving Milestone 1 requires approval of all documents by the AECB, and is conditional on a number of future activities:

- AECB acceptance of Safety Analysis Basis (SAB) documents, which describe the assumptions and methods to be used in safety analysis, and
- consideration or incorporation of any new and significant findings from safety-related Research and Development (R&D), safety analysis or experience from operating plants.

The SABs are formally required for Milestone 2, but the AECB has tied Milestones 1 and 2 together through acceptance of the SABs

2. Identify Potential Problems

This milestone is essentially achieved by AECB Staff review of the design, as described in a Technical Description. Most of the CANDU 3 design is a straight-forward evolution from CANDU 6s operating throughout the world. AECB review concentrated on new design features which represent simplification over operating CANDUs, in particular:

- process and safety systems grouping philosophy
- unidirectional core flow and single-ended refueling
- steel-lined containment without dousing
- distributed control system, and
- computerized safety systems.

When AECB Staff are satisfied they have identified all significant design and safety issues, Milestone 2 is achieved. The safety issues are reviewed through a compliance document, prepared by AECL, which describes the methods used to show compliance with three key safety regulatory documents R-7⁵, R-8⁶, R-9⁷ and the SABs.

3. No Major Problems Foreseen

During the process of achieving Milestones 1 and 2, AECB staff opened actions against the CANDU 3 project to provide more design information or safety analysis. When these actions have been addressed to the satisfaction of the AECB, by more information, or if necessary, by design changes, Milestone 3 is achieved.

There is still discussion on the amount of safety analysis required. AECL expected that a “conceptual” report of analysis, covering the traditional cases which have affected CANDU design, will suffice. AECB staff have indicated that if the analysis is sufficient, achieving Milestone 3 will also represent the equivalence of a construction license for the design. When a site is selected for a CANDU 3, only site specific licensing would be required in order to obtain the actual construction license.

4. Accept Standard Design

AECB staff need to do a thorough review of the detailed design and safety analysis in order to achieve Milestone 4. Milestone 4 is the equivalent of the operating license for the standard design. All actual operating requirements, such as operator training, would have to be reviewed and approved by AECB staff for a real plant.

Progress to Date

Currently Milestones 1 and 2 are almost complete. All documents, except for a number of SABs, have been submitted and reviewed. Almost all of the documents for Milestone 1 have been approved.

The conceptual reports, for accident analysis and probabilistic analysis, have been submitted for Milestone 3. AECB staff review resulted in a number of actions against the CANDU 3 project. AECL has closed a few of these actions but most remain open currently.

For Milestone 4, AECL has produced much of the detailed design description necessary for AECB review, but has not submitted this material yet. AECL’s priority was on the first three milestones.

Successes and Lessons Learned

The process worked reasonably well. It allowed AECL to maintain a current and detailed understanding of AECB licensing requirements as they evolved through the 1980s and 1990s. The experience AECL gained from this process was applied directly to the Wolsong 2,3,&4 plants currently being constructed in Korea. They are being licensed in Korea to Korean and Canadian requirements as of December 1989, and used CANDU 3 work on Licensing Milestones 1 and 2.

There were, of course, technical disputes, but the whole idea of the process is to resolve these before the plant is committed and/or being built. In many cases, design changes were implemented or committed to the design to accommodate AECB concerns. Of course, making these changes during design rather than during construction is a benefit to be realized when the first CANDU 3 is built.

In general, the way up-front licensing worked in detail could only be defined by trying to do it. Much was learned on both sides. In that respect the CANDU 3 experience points the way for future up-front licensing initiatives, such as CANDU 9.

Currently, AECL is devoting much more of the design effort to CANDU 9 (see below) and to repeat CANDU 6s. The regulatory review of CANDU 3 has likewise been re-focused to CANDU 9, and AECL's current effort on CANDU 3 is directed towards schedule definition and cost reduction. However the CANDU 9 licensability review was able to start rapidly by using the lessons learned in the CANDU 3 process and by building on the issues identified and resolved on CANDU 3; without the years of work on CANDU 3, this would not have been possible. Similarly, any agreements reached with the AECB on CANDU 9 will benefit the future CANDU 3 design.

TABLE 1. CANDU 3 UP-FRONT LICENSING IN CANADA

Milestones and Deliverables			
Milestone 1	Milestone 2	Milestone 3	Milestone 4
<i>Licensing Basis</i>	<i>Identify Potential Problems</i>	<i>No Major Problems Foreseen</i>	<i>Accept Standard Design</i>
Licensing Basis Document	Technical Description	Conceptual Safety Report	General Safety Report
12 Safety Design Guides	Compliance with R-7, R-8 and R-9	Conceptual PSA Report	Detailed design
Systematic Plant Review	Safety Analysis Bases	Resolve Major Problems	

4. CANDU 9—Licensability in Country of Origin

The more recent CANDU 9 programme is centred on an evolutionary design of approximately 900 MWe. It is based on already-operating CANDUs (Bruce-B and Darlington), with improvements in the areas of constructability, economics, plant layout, operations and maintenance, and safety. Even so, both domestic and foreign potential users require evidence of

licensability in Canada as of "today". An "up-front" licensing process, using an improved CANDU 3 model, has been established to give this assurance. For CANDU 9, this involves a two-year intensive review by the AECB, which will result in their first report in the summer of 1996 and the final report in January 1997. Specifically the AECB is asked for an informed opinion on the licensability of CANDU 9, as an input to the detailed licensing review by a foreign regulator.

CANDU 9 is not currently viewed as a Standard Product Design. Should a CANDU 9 be sold overseas, the foreign regulator would award a construction licence, not the AECB. Thus much of the detailed licensing would be done overseas after the commitment of the project. The CANDU 9 licensing objective is therefore to get assurance from the AECB, before a project is committed, that CANDU 9 would be licensable in Canada; and that this assurance is in sufficient detail, with sufficient work done to back it up, that a foreign regulator could proceed with confidence. The finding by the AECB should therefore be one of "no fundamental barriers" to licensability in Canada, equivalent to Milestone 3 on the CANDU 3 SPD programme.

The document submission schedule to the AECB ensures that *requirements* are submitted (and agreed) first, followed by the description of how these requirements are *implemented* in design and satisfied in safety analysis. This organization makes it possible to do the review in a two year period, since it ensures that we are not still debating requirements after the detailed design is well advanced.

A summary of the document submission schedule follows. All major documents will have been submitted by mid-1996, allowing time for AECB Staff review and their first report, and resolution of any outstanding issues before the final AECB report in January 1997.

TABLE 2 - HIGH LEVEL DOCUMENT SUBMISSION SUMMARY

Documents	Submission to AECB
FAMILIARIZATION	
Licensing Plan	September 1994
Technical Description Rev. 0	February 1995
REQUIREMENTS DOCUMENTS	
Licensing Basis	January 1995
QA Programme	March 1995
Safety Design Guides	March - May 1995

Documents	Submission to AECB
Systematic Plant Review Methodology	April 1995
Safety Critical Software Standards and Procedures	May 1995 - December 1995
Compliance with Regulatory Documents	May 1995 - August 1995
Human Factors Engineering Programme Plan	June 1995
Safety Analysis Initial Conditions and Standard Assumptions	August 1995
Probabilistic Safety Analysis Methodology	August 1995
Design Requirements for Safety Related Systems	September 1995
Distributed Control System Software Requirements	October 1995
Disposition of Generic Licensing Issues	December 1995
Severe Accident Programme	February 1996
 DESIGN DOCUMENTS	
Flowsheets for Safety Related Systems	September 1995 & February 1996
Overpressure Protection Summary Reports for Safety Related Systems	September 1995 & February 1996
Technical Description Revision	January 1996
Safety Critical Software Sample Implementation	March 1996 - September 1996
Distributed Control System Sample Implementation	March 1996 - September 1996
 SAFETY ANALYSIS DOCUMENTS	
Exclusion Area Boundary	September - December

Documents	Submission to AECB
	1995
Accident Analyses <ul style="list-style-type: none"> • large LOCA • small LOCA • LOCA with loss of Emergency Core Cooling • LOCA with impaired containment • small LOCA • loss of flow • loss of reactivity control • single channel events • steam & feedwater line breaks 	October 1995 - July 1996
Probabilistic Safety Assessment (Level 1)	December 1995 - July 1996

Some particular requirements documents warrant attention:

- The **Licensing Plan** records the deliverables to be submitted to the AECB, and the submittal schedule. When agreed to by the AECB, along with a review schedule, it acts as the road-map through the licensing process.
- The **Licensing Basis** is a high-level listing of the major licensing requirements. It calls up the appropriate regulatory documents and codes and standards, and interprets, in case of ambiguity, how the licensing requirements will be applied. It includes both AECB requirements and the requirements of the foreign regulatory body.
- The **Systematic Plant Review** lists the design basis accidents. In Canada the onus is on the designer/owner to determine and justify a complete set of design basis accidents, and assign them to frequency classes using guidance provided by the Regulatory documents. Each frequency class has an associated public dose limit. Clearly this is an area open to much debate with the regulatory agency, and must therefore be established early on.
- **Safety Design Guides** are the interpretation in detail of the requirements of the safety and regulatory documents on the project. They are written by safety experts in AECL, and act as detailed instructions to designers in the execution of their design. They must be approved by the AECB.
- **Generic Licensing Issues** are those identified by the AECB which apply to more than one plant. New plants are expected to make significant progress in clearing these issues.

Currently AECL is on schedule in submission of documents. AECB reviews, while limited by the requirement to increase resources rapidly, have focused on both the plant requirements and on any features of CANDU 9 that are perceived to be different from as-built CANDUs, particularly on the conversion from the multi-unit Bruce-B/Darlington design to a single-unit.

Disputes naturally arise in the course of such a review. They need to be resolved rapidly. The process is as follows:

- AECL submits each formal deliverable
- AECB Staff formally reply with its review
- an informal meeting is held with AECB Staff to ensure that both sides understand the comments, and to indicate AECL's response
- AECL responds formally to the AECB Staff
- AECB Staff either close off the item, or, if there are issues still in dispute, they are sent up the management hierarchy of each organization, with attempted resolution at each management level, up to the Executive of AECL and the AECB.

At this stage in the review, the process can be said to be working satisfactorily.

5. *Conclusions*

The Canadian approach to minimizing licensing risk relies on those unique aspects of CANDU licensing philosophy—a non-prescriptive, judgmental process which places the primary responsibility for safety on the designer/owner; a well-focused, one-product industry, where all players know the product well; and successful export of this philosophy to CANDU customers and their regulators overseas. The success to date of up-front licensing on CANDU 3 is now being used on CANDU 9 in a shorter time-scale. The result will assure both domestic and foreign customers that they can embark on a project construction without delays due to licensing disputes.

References

¹ M. Joyce, "The Licensing Process for Nuclear Power Reactors", Atomic Energy Control Board Publication AECB-1139 Rev. 1, November 1979.

² P. Marchildon, "Recent Developments in Canadian Nuclear Power Plant Licensing Practices", presented to the 6th. Annual CNA Conference, Ottawa, June 1985.

³ A. Natalizio, "Up-Front Licensing—A New Approach", presented to the 6th. Annual CNA Conference, Ottawa, June 1985.

⁴ "Requirements for the Safety Analysis of CANDU Nuclear Power Plants", AECB Consultative Document C-6, June 1980

⁵ "Requirements for Containment Systems for CANDU Nuclear Power Plants", AECB Regulatory Document R-7, February 21, 1991.

⁶ "Requirements for Shutdown Systems for CANDU Nuclear Power Plants", AECB Regulatory Document R-8, February 21, 1991.

⁷ "Requirements for Emergency Core Cooling Systems for CANDU Nuclear Power Plants", AECB Regulatory Document R-9, February 21, 1991.