DEVELOPMENTS IN CANDU STANDARD PLANT LICENSING

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SUMMARY

AECL is continuing with its goal of completing the standard plant design for the CANDU 3 nuclear power reactor. To date major aspects of the conceptual design and some of the detailed design work have been discussed with the Canadian nuclear regulatory agency, the Atomic Energy Control Board (AECB).

The Standard Plant Design (SPD) envelope has been chosen to accommodate the characteristics of a wide variety of sites in Canada and around the world. One of the key objectives of the project is to ensure the standard plant design is licensable in Canada. This is to be accomplished prior to the AECB issuance of the construction licence for the first unit. Approval from the AECB is required to reduce the plant owners' risk and achieve the 35 month construction schedule established for the project.

The focus of the early years of the project was to agree on and document the design requirements and then derive the conceptual design. The detailed design work could proceed only with agreement on the major design-related licensing pre-requisites, thus reducing the risk and associated costs of major design changes which might be required by the regulatory agency during the detailed design or construction phases. The licensing objectives for the first years included establishing the licensing basis for the SPD, review of the unique features of the CANDU 3, agreement on the Safety Design Requirements, agreement on the Systematic Plant Review and then agreement on the Safety Analysis Basis. These will then be used to ensure the detailed design and safety analysis proceeds on a mutually understood basis.

Consultative Document C-6 "Requirements for the Safety Analysis of CANDU Nuclear Power Plants" was previously used on a trial basis in the licensing of Darlington. For CANDU 3, the traditional single/dual failures licensing approach has been abandoned by the AECB. These up front licensing discussions on the CANDU 3 provide the first opportunity for the AECB and the industry to explore what full implementation of the Consultative Document C-6 as the sole basis for judging the acceptability of the safety analysis entails. Clarifications of the draft requirements utilized in the Darlington licensing process have been discussed and these have resulted in the production of unique licensing documents such as the systematic plant review. In this paper, we review the issues discussed in the licensing process and outline their resolution.

INTRODUCTION

AECL CANDU continues to update the CANDU product to provide improvements in:

- safety and reliability
- capital and operating costs
- construction schedule
- construction techniques
- maintenance and operation

To remain an environmentally preferred alternative to coal fired plants, or alternative energy sources such as solar power, bio-mass, and wind generated, the CANDU product must be technically advanced and economically competitive. Therefore AECL is continuing with its program to design and license a standard 450 MW(e) plant (CANDU 3) which has a 35 month construction schedule from start to in-service operation, and has been pre-approved by the nuclear regulatory authority.

The site acceptance process, including the environmental assessment and impact on the local area, and the application for operating licence from the nuclear regulatory authority will follow once an owner/operator's commitment has occurred.

STANDARD PLANT DESIGN PROGRAM

The design of the standard plant has proceeded such that the majority of conceptual issues have been resolved and some detailed design work has commenced. The design envelope (Reference 1) was chosen to accommodate the characteristics of a wide variety of sites in Canada and around the world.

Design Principles

The design principles remain:

1. enhance or improve traditional CANDU advantages including safety, low radiation exposure, high capacity factor, ease of maintenance and low operating cost;

2. reduce the capital costs, construction schedule and unit energy cost;

3. standardize the plant design so it is suitable for various sites world-wide, without significant design changes or modifications;

4. create separation and independence among the plant structures and systems to facilitate construction and contractual options such as shared financing, utilization of partners and subcontractors without introducing significant design or documentation changes;

5. employ state-of-the-art technology, include design, construction, operation and project management methodologies consistent with twenty-first century approaches;

6. For plant components:

    a. maximize life expectancy,

    b. enhance ease of replacement at the end of life - quick and simple, without the need for complex tooling or an extended outage, thereby minimizing radiation exposure,

    c. minimize complexity and cost, and

    d. minimize installation time and cost;

7. For maintenance and in-service inspection:

    a. maximize the operating period between scheduled maintenance outages and in-service inspection,

    b. minimize the outage period duration to 21 days per year,

c. maximize the operating period between major maintenance outages to 15 years.

d. minimize the major maintenance outage duration for major equipment replacement (fuel channels, steam generators), major system modification or modernization (controls, computers) or major equipment refurbishment (re-blade the turbine).

Design and Safety Approach

The design approach has been to establish a comprehensive set of design requirements, with emphasis on the safety and licensing requirements, prior to the start of the detailed design work. These requirements have evolved during the conceptual design phase and are now included in the safety design guides and the design requirements documents (see Figure 1). The safety team has been integrated with the design team to ensure these requirements were clearly understood by the designers at the start of the project.

After the conceptual design of a system is completed and documented, the requirements and the proposed implementation are reviewed by a design review panel. Fifty-four of the some fifty-seven formal design reviews have taken place. These have included representation and participation from the utility staff and knowledgeable experts independent from AECL.

STATUS OF THE LICENSING PROGRAM

Standard Plant Licensing Plan

AECL has been following an up-front approach to licensing for the standard plant design. This up-front licensing approach enables all parties to better understand the project licensing requirements and helps reduce the project risks and uncertainty. Before proceeding with the site approval, detailed design, and construction phases, the major design-related licensing pre-requisites will be agreed by the designers and licensing authorities. This process helps to clarify the safety and design intent and reduces the number of design changes that may arise during construction because of the regulatory review process. Precise commitments are made and clarification and agreement of requirements are achieved by all parties before significant expenditures occur.

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Originally, as part of the up-front licensing discussions on the CANDU 3, AECL had planned to follow the licensing approach described in ACNS-4; the most current licensing approach available in Canada as of June 1983 (Reference 2). However, further discussions with the nuclear regulatory agency showed that the advances and understanding gained during the Darlington licensing process should be applied to the CANDU 3. Thus the CANDU 3 SPD provides the first opportunity for the AECB and the industry to explore what licensing implementation of Consultative Document C-6 "Requirements for the Safety Analysis of CANDU Nuclear Power Plants" (Reference 3) as the basis for judging the acceptability of the safety analysis entails without relying on the older single/duel failure dose limits. Clarifications of the draft requirements utilized in the Darlington licensing process have been discussed and these have resulted in the production of unique licensing documents (Reference 4).

Licensing Requirements and Documentation

So far in the licensing process, AECL has submitted twelve Safety Design Guides (SDG) (Table 1) which describe the safety design requirements. These have been reviewed by the AECB and all major comments have been addressed.

Additionally, to ensure compliance with the AECB Regulatory Documents for Special Safety Systems (References 5, 6, and 7), AECL has submitted a document which compares the individual clauses of the Regulatory Documents with the clauses of the SDGs and/or the design documentation. Where operating, commissioning, maintenance and training requirements are presented in the regulatory documents, AECL has been recording all the requirements on behalf of the plant owners and/or operators, so their intent and purpose can be discussed with the AECB.

Preliminary probabilistic safety assessments have been performed as part of the conceptual design. These documents have provided valuable risk and safety analyst insight to the design and helped derive reliability requirements for the system designers. This information has also been invaluable as input to the exhaustive and comprehensive systematic review process on the CANDU 3 design (Reference 4). This report identifies for the major systems those failure modes which could possibly result in the release of radionuclides from their normal locations. Using a failure modes and effect analysis technique, the report identifies all serious process failures. Derivation of a combination of these failures with the unavailability of systems or equipment whose action would mitigate the consequences of these events will be found in the Safety Analysis Basis (SAB) documents, which are expected to be issued to the AECB next year.

Licensing Topical Meetings & Correspondence

Special effort has been made to arrange topical meetings with the AECB, the Canadian utilities and plant operators on the novel standard plant design features and the traditional safety issues. As part of this process, assessment documents (Table 2) have been submitted for early AECB review and approval.

Major safety concerns as diverse as the systematic plant review, reactor power pulse, grouping of plant systems and plant layout, single ended refuelling, pipewhip, environmental qualification and tornado design have been documented in the assessment reports. Further correspondence has occurred on the requirements for SDS1 depth, CHF, post-LOCA instrument air design, new and irradiated fuel transfer, the need for main steam isolating valves, AECB consultative document C-83 (Reference 8), computer code documentation requirements, containment equipment hatch testing, safety analysis and licensing requirements for beyond design basis events, containment electrical penetrations and fire protection.

Standard Plant Documentation

In addition to the assessment documents submitted, while obtaining standard plant design approval, the documents listed in Table 3 have been or will be submitted for regulatory approval.

Discussions are underway to answer AECB questions and resolve outstanding issues on the submitted documents. These documents will be supported by the detailed design and analyses documents listed in Table 4, some of which have already been submitted to the AECB.

Progress to Date

For the CANDU 3 SPD, AECL is aiming to resolve issues early in the licensing process, to the satisfaction of all parties, thus reducing risks. Exchanges of correspondence and discussions on the Safety Design Guides have progressed to the point where agreement on the SDGs is essentially complete, with only minor editorials outstanding. In response to the AECB and potential utility clients needs and requirements, a number of design changes and modifications have occurred. For example, the AECB's desire to see much more extensive information on the reactivity holdups, transient analysis of sub and superprompt critical ranges, the computer codes used and shutdown system performance to avoid operation in superprompt critical modes, resulted in a re-design of the heat transport system to include four heat transport pumps and four reactor inlet headers. Furthermore, the AECB was concerned about the capability to recover from a fuelling machine failure, since the concept of single ended refuelling was perceived by some to be a major departure from past designs. To alleviate these concerns a thorough review of the significant event reports involving the fuelling machine was conducted. Additionally, as the design concept progressed it was decided that the channel inlet end fitting would be modified to have a full bore hub, compatible with a special flask/grappling machine that would permit defuelling capability for emergency conditions.

There were also minor changes as a result of internal and AECB design reviews. For example, the number of local air tanks in the post-LOCA instrument air design was significantly reduced from past plants because of utility concerns. As a result of AECB concerns, the containment electrical penetrations were re-designed so that they will be individually testable.

An important aspect of the CANDU 3 SPD is its grouping and separation philosophy. Plant systems are laid out systematically with emphasis on separation of safety systems from process systems and the separation between safety systems. There has been several discussions on this subject and the AECB has agreed that the CANDU 3 concept of grouping, separation and layout provided important improvements in safety. The design team is putting special effort to ensure that the benefits of the CANDU 3 grouping and separation concept is carried out in the detail design. A natural fall out of the grouping/separation concept is that it is easier to provide tornado protection to safety systems without inhibiting accessibility and maintainability because of heavy concrete barriers. In addition, the number of penetrations has been reduced and labyrinths have been added in front of all unprotected doors and penetrations so there is no or a very minute chance of tornado missile damage. Pipewhip protection also benefits from the improved separation and layout design since there is better placement of process systems and less chance of consequential damage to safety systems. The AECB agreed that the design methodology for pipewhip protection is reasonable.

An enhanced approach was used for the systematic plant review for initiating events; the details can be found in Reference 4. Positive verbal feedback has been received from the AECB on this new approach. There were presentations and discussions on environmental qualification (EQ) and an encouraging response on the process was received. To ensure the well defined processes are followed, the AECB is scheduling an audit on the CANDU 3 EQ SDG and EQ procedure later this year.

Since the need for fire prevention, detection, mitigation and suppression was incorporated into the SPD at the beginning of the project, the AECB has acknowledged that this is an improved, systematic approach to fire protection. Improvements in the grouping, separation and layout design also made it easier to provide clear, separate fire protection to safety and process systems.

Other important issues that have been discussed include: CHF methodology which AECB has accepted that it will not be an issue until we apply for a high power license (The design/analysis team will keep abreast of the on-going generic CHF tests.); improvements in computer code documentation, verification/validation, and version control; the requirements for main steam isolating valves; and safety analysis and licensing requirements for beyond design basis events.

Finally, the AECB has performed its first audit on a large scale AECL project in some ten years. Corrective measures are being taken to remove the deficiencies identified via the two recommendations and six quality observation action notices. As was mentioned earlier the AECB will be following up this audit with a more specific audit on the EQ program.

New requirements have also arisen, such as the need for an on-site nuclear simulator to train the operating personnel and increased licensing fees for the review of the SPD. The CANDU 3 project team is keeping abreast of these requirements as they evolve.

CONCLUSIONS

The emphasis on specifying requirements before proceeding to the detailed design phase has necessitated greater co-operation and co-ordination among the design and safety staff. The safety team has been integrated with the design team to ensure a full set of safety and design requirements are documented and understood before component assembly and fabrication, and project construction and implementation occurs. Conflicting requirements among economics, schedule, design, construction, reliability, maintenance, operation, testing, decommissioning, environment and safety continue to be resolved.

Dialogue on various subjects has been occurring among the AECB, the Canadian utilities, and AECL. Several design changes or improvements have been made as a result of these design reviews. Major issues including the systematic plant review, reactor power pulse, grouping of plant systems and plant layout, single ended refuelling, pipewhip, environmental qualification and tornado design have been resolved satisfactorily. The design team will ensure that the improvements from the conceptual design are fully implemented during the detail design phase.

The use of PSA tools early in the conceptual design, and their continued updating as part of the systematic plant review (and later as part of the plant generic PSA), ensures a comprehensive list of postulated events will be analyzed by both deterministic and probabilistic techniques.

The continued use of up-front licensing and agreement on the requirements *before* proceeding to the next phase in the design, construction and eventual operation of the plant should lead to a reduction in risk to the future operators and owners of the plant.

REFERENCES

(1) M. BONECHI, et. al, "CANDU 3 Standard Plant Licensing", Tenth Annual Conference of the Canadian Nuclear Society, Ottawa, Canada, June 4-7, 1989.

(2) AECB REPORT, INFO-0116, "ACNS-4, Recommended General Safety Requirements for Nuclear Power Plants", by the Advisory Committee on Nuclear Safety, June 1983.

(3) AECB CONSULTATIVE DOCUMENT C-6, "Requirements for the Safety Analysis of CANDU Nuclear Power Plants", issued for comment June 1980.

(4) R. JAITLY, "CANDU 3 Systematic Plant Review - A New Approach", 13th Annual Conference of The Canadian Nuclear Society, Saint John, New Brunswick, Canada, June 7-10, 1992

(5) AECB REGULATORY DOCUMENT R-7, "Requirements for Containment Systems for CANDU Nuclear Power Plants", A Regulatory Policy statement, Effective date: February 21, 1991.

(6) AECB REGULATORY DOCUMENT R-8, "Requirements for Shutdown Systems for CANDU Nuclear Power Plants", A Regulatory Policy statement, Effective date: February 21, 1991.

(7) AECB REGULATORY DOCUMENT R-9, "Requirements for Emergency Core Cooling Systems for CANDU Nuclear Power Plants", A Regulatory Policy statement, Effective date: February 21, 1991.

(8) AECB CONSULTATIVE DOCUMENT C-83, "Proposed General Amendments to the Atomic Energy Control Regulations", issued for comment April 28, 1986.

Table 1 Lust of Safety Design Guides	
1.	Safety Related Systems
2.	Seismic Requirements
3.	Environmental Qualification
4.	Grouping and Separation
5.	Fire Protection
6.	Code Classification
7.	Periodic Inspection
8.	Radiation Protection
9.	Tornado Protection
10.	Pipe Rupture Protection
11.	Decommissioning
12.	External Flooding

Table 2 Subjects of Topical Meetings and Assessment Documnents	
1.	Grouping & Plant layout
2.	Containment
3.	Containment electrical penetrations
4.	Post-LOCA instrument air
5.	Single ended fuelling
6.	Distributed control
7.	Human factors
8.	ECC
9.	CHF
10.	Reactor power pulse
11.	SDS1 depth
12.	Tornado
13.	Environmental Qualification
14.	Pipe whip
15.	Aircraft impact
16.	Fire protection

Table 3 Licensing Documents Proposed to be Submitted for Standard Plant Design Approval	
1.	Standard Plant Licensing Basis and Systematic Plant Review of Initiating Events - submitted
2.	Safety Design Guides (SDG) - submitted
3.	Conceptual Safety Report (CSR) - submitted
4.	Standard Plant Safety Report (SPSR)
5.	Conceptual Probabilistic Safety Assessment (CPSA) - submitted
6.	Standard Plant Probabilistic Safety Assessment (SPPSA)
7.	Assessment of Common Cause Events
8.	Assessment of Low Probability Events
9.	Regulatory Compliance Documents - 1st iteration submitted
10.	Overpressure Pressure Protection Report
11.	System Classification List (SCL)
12.	Safety Analysis Basis (SAB) Documents - examples submitted
13.	Safety Analysis Data Lists (SADLs)
14.	Computer Codes' Documentation - examples submitted
15.	Register of Licensing Documentation - updated on a continuing basis
16.	Minimal Allowable Performance Standard (MAPs) Documents

Table 4 Design Documents Proposed to be Submitted for Standard Plant Design Approval	
1.	Design Requirements (DRs) - submitted (selected systems)
2.	Design Guides (DGs) - submitted (selected topics)
3.	Design Descriptions (DDs) - submitted (selected systems)
4.	Standard Plant Design Quality Assurance (QA) Manual - submitted
5.	AECL CANDU Engineering QA Manual - submitted
6.	AECL CANDU Procurement QA Manual - submitted
7.	Design specifications for components
8.	Decommissioning Plan - submitted
9.	Reliability Reports for systems
10.	Human Factors (HF) Plan
11.	Post-LOCA (loss-of-coolant accident) Radiation Management Study
12.	Environmental Qualification (EQ) Program - submitted
13.	Radiation Exposure Control Program
14.	Periodic Inspection Program
15.	Shutdown Systems Trip Computer Software QA Plan